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AN ANALYSIS OF COMBAT AIRCRAFT AVIONICS PRODUCTION COSTS.(U)
MAR 81 J DRYDEN, T BRITT F49620-77-C-0023
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Describes research directed toward developing parametric estimating relationships for the production costs of avionics suites and systems. The research sample comprised 17 combat aircraft and their avionics equipment. Potential explanatory variables were selected based on interviews with manufacturers about factors affecting avionics costs and the appropriateness of the variables for use in planning studies early in system acquisition. Multivariate regression analysis techniques were used to determine the statistical properties of candidate estimating relationships for whole suites and individual systems. The estimating equations derived for suites were generally satisfactory but not always as statistically efficient as desirable. Attempts to derive estimating relationships for avionics systems were much less satisfactory but offer improvements over the simple cost per pound metrics often used. The authors conclude that objective means for expressing technology change and its importance for avionics cost estimation remain a concern for future reseach. 140 pp. Bibliog. (DGS)

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A RAND NOTE

AN ANALYSIS OF COMBAT AIRCRAFT AVIONICS PRODUCTION COSTS

J. Dryden, T. Britt, S. Binnings-DePriester

March 1981

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PREFACE

Reliable means for estimating the costs of advanced avionics equipment have been high priority needs of the Air Force cost analysis community for some time. This Note describes the results of research undertaken to provide estimating methods for avionics production costs suitable for planning studies, preliminary design/cost tradeoffs, Independent Cost Analyses (ICAs), and other situations in which parametric procedures are appropriate.

The research was directed at providing an understanding of the cost relationships and deriving estimating methods for both whole avionics suites and individual avionics systems (e.g., computers, displays, active electronic countermeasures) for advanced combat aircraft. The results are inconclusive. The estimating equations derived for suites are generally satisfactory, but not always statistically as robust and efficient as desirable. Attempts to derive estimating relationships for avionics systems were much less satisfactory, although our results, with a few exceptions, are improvements over the simple cost per pound metrics often used for avionics estimating. The results also provide useful insights about significant cost parameters in avionics systems.

The research reported here should be helpful to Air Force, DoD, and industry analysts concerned with making or analyzing avionics cost estimates, particularly for planning purposes. The results, both satisfactory and unsatisfactory, should also be useful references for planning future research on avionics costs.

This Note contains descriptive information on the explanatory variables and technical/performance data for avionics suites, systems and individual system components. Cost data are also provided for the suites, but much of the data for the systems and components are designated as proprietary by the manufacturers and are not presented here.

The Note was prepared for Project AIR FORCE as part of the Resource Management Program project entitled "Cost Analysis Methods for Air Force Systems.

SUMMARY

This Note describes the results of recent research on estimating relationships for the production costs of avionics equipment used in modern combat aircraft. The goal of the research was to develop parametric estimating relationships, based on objective variables that may be used in planning studies early in the system acquisition process (e.g., prior to DSARC II) when little design information is available, or as a means of cross-checking estimates prepared with other methods.

The research centered on a sample of 17 modern combat aircraft and the avionics equipment installed within them. Potential explanatory variables were selected on the basis of interviews with manufacturers about factors affecting avionics costs and the appropriateness of the variables for use in planning studies. An important analytical problem was to find variables that effectively captured the rapid technology change that has characterized avionics during the past several years. Multivariate regression analysis techniques were used to determine the statistical properties of candidate estimating relationships for two levels of avionics equipments: whole avionics suites (e.g., all the avionics for a given aircraft) and individual avionics systems (e.g., computers, displays, and electronic countermeasures).

For avionics suites, we obtained logical and statistically significant relationships based on size variables--aircraft empty weight and avionics weight, power, and volume--year of first flight (a technology variable) and an all-weather capability dummy variable. Care must be exercised in applying the year of first flight variable,

however, as it implies a time dependent rate of technology change that might not be sustained in the future.

The analyses of avionics systems were not as promising as those for suites. The systems were analyzed first as a single group and were then subdivided into eleven functional groups. This grouping provided relatively homogeneous subsamples for which we analyzed potential estimating relationships based on weight, volume, and power variables, and technology variables that distinguished among vacuum tube, solid state, and integrated circuit equipments. These particular technology variables added little to the usefulness of the tested relationships, and, on the whole, the relationships exhibit an undesirable amount of unexplained variance. Thus, objective means for expressing technology change and its importance for avionics cost estimation remain a concern for future research. For most avionics groups, however, these results are an improvement over simple cost-per-pound metrics of the type often used in planning studies.

ACKNOWLEDGMENTS

The authors wish to acknowledge the contribution of co-workers Bruce Armstrong, Joseph Balding (USAF), Loanne Batchelder, Patricia CoNine, Joseph Large, Mary Jo Parise, and Jimmy Wilson for their assistance in data collection, tabulation and formatting, and statistical analysis. In addition, we would like to thank the many government and contractor personnel whose assistance we received in compiling the data base.

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I. INTRODUCTION

The mission capabilities of avionics systems in modern combat avionics have increased enormously over the past few years. This increase in capability has been accompanied by similar changes in the cost of avionics systems and has increased their contribution to the total cost of acquiring new combat aircraft. Cost analysis techniques have not, however, kept pace with the growing significance of avionics, and available techniques generally lag behind those routinely used for predicting and analyzing the costs of airframes and turbine engines. In particular, no reliable and widely accepted set of parametric estimating techniques are available for addressing avionics production costs early in the acquisition process (e.g., prior to DSARC II or for planning studies or preliminary design/cost tradeoffs) when design-specific information is not available or for cross-checking estimates prepared by engineering- or analogy-based methods (e.g., in Independent Cost Analyses). Instead, many planning studies rely on cost-per-pound rules of thumb to make first-order estimates of avionics production costs.

This Note describes the results of our research on avionics production costs and our attempt to meet the need for reliable parametric estimating techniques. The research centered on avionics systems and major equipments found in a sample of 17 modern combat aircraft ranging from the A-4M to the FB-111A (but excluding other bombers). Potential estimating relationships were examined at two levels: whole avionics suites for new aircraft and individual avionics systems (e.g., computers, displays, and active electronic countermeasures). For both instances, potential explanatory variables were selected to match the information likely to be available early in the design and planning process for new systems. For example, we could reasonably expect a cost estimator involved in a planning study to have a reasonable knowledge of the functions to be performed by the avionics and fairly accurate estimates of its weight; we would not, however, expect that estimator to know the number of piece-parts contained within a planned avionics system.

A major problem in developing avionics estimating relationships--both in this research and in past efforts at Rand and elsewhere--is how to capture and represent the rapid change characterizing the electronics technology of avionics. Over the past several years advances in that technology have consistently led to the accomplishment of more individual functions per unit size of avionics equipment and at lower cost per function. Simultaneously, avionics designers have demanded that more functions be performed in the aggregate (to meet mission requirements) so that the overall effect on costs has been positive and large. After examining several possible means for expressing the effects of technological change, we settled on the use of a time variable keyed to year of first flight in developing regression equations for avionics suite costs. Explicit technology categories--vacuum tubes, solid state and integrated circuits--were used as binary variables in deriving predictive equations for avionics systems. (In both cases, the technology-related variables were combined with other mission and physical variables).

The results were mixed. The suite equations, including the time variable, are satisfactory both statistically and intuitively. The time variable implies, of course, that the rate of technological change is constant over time--an implication that must be treated with care when extrapolating more than a very few years beyond the range of the sample. The avionics systems equations, on the other hand, are much less satisfactory and the technology variables added little to the explanatory power of these equations. Thus, objective means for expressing technology change remain a concern in the estimation of avionics costs.

The results of the research presented here do not meet the full need for reliable estimating techniques for avionics production costs. Our analyses of suite costs yielded acceptable relationships for suites, but some of the residuals are large and, as noted above, the technology change phenomena is "explained" only in terms of time. For avionics equipments, the results are much less satisfying and the regressions are characterized by significant unexplained variance. We believe, however, that the results provide useful insights about the cost characteristics of avionics and an improved, if not wholly satisfactory, basis for generating cost estimates.

PLAN OF THE NOTE

The research approach and data base for our study are discussed in Section II. Section III presents the analysis of avionics suite costs, and Section IV discusses the analysis and results for avionics systems. Our conclusions and recommendations are included in Section V.

The Note contains two appendices: Appendix A presents descriptive and cost data for avionics suites and Appendix B contains data used in our analysis of systems. Cost data for several of the components within the systems are manufacturer proprietary; hence only aggregate cost information is presented for systems.

II. RESEARCH APPROACH, DATA, AND ADJUSTMENTS

In this section we review the approach taken in our research, the data base used and the adjustments made to that data.

RESEARCH APPROACH

The results presented in Sections III and IV are based primarily on standard techniques of multivariate regression analysis. The critical part of the research, of course, was the determination of the predictive models to be tested with the regression analysis. Hence a major part of our effort was the investigation of explanatory variables for avionics production cost. Three considerations were paramount here: (1) the variables must have a logical and substantive relationship to the cost of producing avionics; (2) information on the variable must generally be available to analysts early in system design; and (3) the variables should be objective and easily verified. (The latter is particularly important for estimating methods that may be used in the preparation of Independent Cost Analyses).

We interviewed government and industry engineering and manufacturing personnel to identify aspects of avionics equipment that influenced production cost. This process provided the theoretical basis for the variables we later included in our statistical analyses but also turned up variables which could not be used. Lack of an objective basis for prediction disqualified many complexity concepts, while nonavailability of data prevented us from using piece-part count (an effective estimating variable for near-term production projects). Some suggestions proved to be without merit, such as the use of density as a technology indicator. A review of the data showed that technology and density do not correlate, indicating that other factors, such as cooling requirements, have dominated technology growth. For our final analyses, we developed candidate explanatory variables in five areas: size; mission or function; environment (suites only); armament (suites only); and technology. In the following discussion we examine each area as it pertains to both suites and systems, indicating the rationale for the variables chosen and for those excluded.

Size

The size of an item is an intuitively satisfying and generally valid, if imperfect, indicator of the cost to produce it. However, previous uses of size variables in avionics estmating have not been satisfactory. We use aircraft empty weight (suites only) and avionics weight, volume and power variables as various measures of size in the analyses that follow. Other variables, discussed in the following paragraphs, are intended to normalize sample observations so that the size variables become predictive. Weight is the size characteristic for which data are most often available for planning estimators. But our investigations indicated that in some instances volume or power data are more readily available, thus the inclusion of these variables. For those instances in which data are available on more than one variable, the multiple estimating equations may be used for cross-checking estimates. In order to avoid problems of multicollinearity, we did not attempt to develop equations incorporating more than one of the size variables.

Mission/Function

An obvious way to develop homogeneous samples is to sort observations based on what they accomplish. At the suite level we chose mission characteristics of the aircraft as our indicators. The four binary categorical (dummy) variables that we included are: All-weather, Air-to Air, Air-to-Ground, and Penetrating (Active ECM). These are based on the entire suite capability and are not indicative of a particular piece of equipment. For example, an all-weather aircraft generally has an inertial navigation set (INS), but in our sample the A-4M is an exception to this rule. All-weather capabilities are a function of the radar, display, and armament capabilities of the aircraft, as well as the INS. Much the same sort of discussion applies to the Penetrating capability, which could range from a single simple jammer to a battery of complex devices. The point is that the entire suite must be characterized rather than the individual components to reflect the interplay among systems.

The basis for sorting at the system level was componentry function. We sought to group systems with similar component types (rather than physical function) to support our size assumptions. Thus electronic countermeasures fall into three groups: Active ECM (radiating devices), Passive ECM (nonradiating devices, such as radar warning receivers), and Electromechanical Devices (chaff/flare dispensers). Similarly, radio communications and identification-friend-or-foe systems are grouped together, and inertial navigation systems are grouped with other gyroscopic devices. In this fashion we developed 11 functional groups (listed in Section IV). We were influenced to a certain extent by the need to maintain a group size large enough for analysis. Some of the groups do not follow the organization of avionics equipment in the Work Unit Code System, but the group specifications of Appendix B provide ample information to determine the appropriate group for equipment whose cost is to be estimated.

Environment (Suites Only)

We identified two environmental effects on avionics production cost: carrier basing and the presence of an internally mounted gun. Carrier basing generally implies more complex avionics because of restrictions on the availability of shipboard support equipment and the problems presented in calibrating systems on a moving platform. The gun introduces vibration and chemical byproducts into the avionics environment, requiring added care in design, placement, and construction. Because of difficulty in attributing the gun capability to multimodel aircraft such as the F-111 series, we did not use the gun as an explanatory variable.

Armament (Suites Only)

We included a Radar Launch Guided Missile capability as an explanatory variable in our avionics suite analysis. Radar launch guided missiles, such as the AIM-7 Sparrow, require significant capability of the radar and fire control systems of the suite, much more than does an infrared homing missile, such as the AIM-9 Sidewinder. Further distinctions in missile capability, such as semiactive versus active radar guidance, could not be implemented with our data base.

Radar bombing was also considered as an armament explanatory variable and indeed this capability has a significant effect on suite configuration and cost. The cost, however, depends on the degree of accuracy and other characteristics of the radar bombing system that are not effectively represented by a binary variable. Since we were unable to reliably depict the level of bombing capability among the aircraft in our sample, we excluded radar bombing as an explanatory variable.

Technology

Perhaps the greatest problem faced in avionics cost estimating is the lack of homogeneity in the historical data base caused by the rapid growth of microelectronic technology over the past several years. We have attempted to capture the effects of technology by using time (aircraft first flight date) in our suite case and a technology indicator in our system level case.

The use of an aircraft first flight date as a technology variable has logical appeal, but it presents problems as well. Since technological development is often aimed at performing essential functions more efficiently, we can generally expect that the cost per unit of functional accomplishment will decrease over time. (That the cost per unit size will increase is an empirical observation that is not a direct outcome of the technological development process.) Nevertheless we can reasonably expect that there should be some functional relationship between cost and time under conditions of improving technology.

The problem arises when we consider the nature of that functional relationship. Unlike the case presented by simple size variables, we cannot assume that uniform scaling of cost with time will occur. We cannot even be certain that a continuous functional relationship exists: The time trend observed in the data is not necessarily an indication of the course of future technological growth. The first flight date represents the technology level that was available to the suite designers of the aircraft in our sample. Extrapolation of the time trend beyond a very few years can produce noncredible estimates. Thus, subjective assessments external to the quantitative model must be made to evaluate properly the time-related input variable for estimating future avionics suites. (Possible approaches to avoiding unwanted outcomes in using the first flight date variable are discussed in Section III.)

In our system level analyses, we used discrete categories to characterize the technology of the individual systems, thus avoiding the use of time as an explanatory variable. Systems were categorized as being of "vacuum tube," "solid state" or "integrated circuit" technology. While this categorization is reasonably objective, it suffers two major drawbacks. First, many systems incorporate more than one of the above types of technology. For these it would have been more apropriate to indicate percentage representation or develop some weighted avarage measure of technology. Secondly, the three levels of technology we use are not sufficient to distinguish the technological options available today. This is particlarly the case for integrated circuitry, where distinctions should be made among small, medium, and large scale versions. We did not, however, have the detailed data or the number of observations required to develop a more discriminating means of representing technological influence in avionics systems. Despite its limitations, the three-group categorization does provide a means of measuring technology's influence on cost that does not suffer from the uncertainties associated with the use of time as a predictive variable.

We also explored other approaches to representing technology. These included the use of subjective assessment scales and attempts to find an independent leading series representing technology that could be correlated with other variables within our data base. These alternative approaches were not successful and were not tested in our regression analyses.

DATA AND ADJUSTMENTS

An important part of our research involved the collection of cost and technical data and the identification, when possible, of alternative sources for such data. The data base consisted of suite and system information for the following aircraft:

A-4M	A-10A	F-4J	F-111A
A-6E	F-4C	F-5E	F-111D
A-7D	F-4D	F-14A	F-111E
A-7E	F-4E	F-15A	F-111F
			FB-111A

It was necessary to adjust the data for consistency in number of units produced and the year-dollars involved. The nature of the data available for the study and the adjustments made to them are discussed in this section.

Source of Data

Most of the data used here were taken from an earlier Rand study that contains both classified and proprietary data. We were unsuccessful in our efforts to supplement that study from contractor sources and only government sources were used in updating the original data base. We collected updated suite data for the A-10 and F-15 from the respective program offices and data on individual systems from various Air Force and Navy sources. We did not use summary data sources such as are found in Air Force TO 00-25-30, Technical Manual, Unit Costs of Aircraft, Guided Missiles and Engines, because of the greater visibility offered by suite data at the system level and our confidence in its accuracy.

The reader will note many omissions in the data contained in Appendices A and B. Much of our effort was aimed at filling in such blank spaces in our data base. To this end we reviewed historical records at the various government agencies and contacted the offices responsible for the ongoing support of aircraft systems no longer being acquired. While we were able to acquire some new information, it is apparent that current data systems are not oriented toward the retention of acquisition information. The following paragraphs further specify the nature of the data problems we faced and discuss the adjustments we made.

Level of Detail

We collected data at the "system" level (i.e., radar set, ECM set, radio set, etc.), denoted by the Joint Electronics Type Designation System "AN" nomenclature system. An example of this level of detail is the ARC-164 UHF Communications Set. It became apparent during our study that this nomenclature system does not uniquely identify a group of equipment. For the example system above, we collected separate sets of costs and specifications for the A-10 and F-15, each substantially different from the other. A search of historical avionics records revealed many examples of the nonuniqueness of the AN system. We resolved data conflicts resulting from this situation by selecting the unit with the highest production quantity. We were also cautious in combining data from different sources for any particular system.

Type of Data

With few exceptions, our cost data are "costs to the government," or producers' prices. These amounts contain profit and general and administrative (G&S) charges, which vary from contract to contract, depending on such factors as financial risk, business volume, and competition. In order to use costs-to-the-government type data in our analysis, we assume that fee and G&A are distributed without bias relative to equipment costs and characteristics.

Cost-Quantity Aspects

A further complication to the analysis results from the cost-quantity aspects of the avionics data. For some equipment we have average cost by lot and lot quantities; for these we could calculate a learning curve slope and 100th unit cost, the accuracy depending on how well cost to the government tracks actual cost. For other equipment the cost data relates to aircraft rather than to avionics quantities. For still other equipment no lot data were available at all, only estimated 100th unit cost. In many cases, average lot data could not be attributed to any particular unit (especially true for Government Furnished Equipment).

Previous studies have dealt with data problems of this kind by extending all costs to the 1000th unit to minimize the impact of learning curve variations. Estimates would then be adjusted with an average learning curve slope. We found the variation in learning curves too large to allow the use of this procedure. Rather, in the systems case, we preferred to analyze those systems for which we had 100th unit costs, leaving the uncertainity of the learning curve as a topic to be addressed once an estimating procedure was in hand.

Inflation Adjustment

No single avionics inflation index was available with which to adjust historical costs to fiscal year (FY) 1978 dollars. Therefore, we used several sets of indices, as shown in Table 1.

The Air Force Aeronautical Systems Division (ASD) avionics procurement index was used to adjust all but newly collected A-10 and F-15 data to FY75. This index has been discontinued, so we used the AFR 173-10 procurement index to adjust these FY75 costs to FY78. A-10 avionics procurement began in FY75; all lot data were adjusted to FY78 by using the AFR 173-10 index. F-15 data were available from the SPO in FY76 dollars; these were adjusted to FY78 by using the AFR 173-10 index.

Table 1

INFLATION INDICES

	AFR 173-10[a] (2 May 77)	ASD AVIONICS (12 July 75)	F-15 AVIONICS[a] (1975)
FY59	60.1	56.0	--
60	59.6	57.3	--
61	60.8	58.6	--
62	60.1	60.0	--
63	60.2	61.5	--
64	60.4	62.8	--
65	61.2	64.0	--
66	63.2	65.7	--
67	65.4	68.3	--
68	67.6	71.8	--
69	69.8	75.5	--
70	72.5	78.8	--
71	75.8	82.3	--
72	78.8	85.9	--
73	82.1	89.5	80.6
74	87.4	94.1	90.0
75	100.0	100.0	100.0
76	107.4	--	109.8
76TQ	111.0	--	--
77	115.1	--	--
78	122.1	--	--

SOURCES:

1. Comptroller of the Air Force, USAF Cost and Planning Factors, Volume I, AFR 173-10, May 2, 1977.
2. Aeronautical System Division, Cost Research Report Number 110B, July 12, 1975.
3. F-15 System Program Office.

[a]Rebased to FY75 for comparison.

Suite versus System Data

In contrast to the system level, where we edited the data base to include only 100th unit costs, our suite level data base is comprehensive. The cases treated at the suite level use, first, aircraft empty weight and, then, three avionics characteristics as primary size variables. It was necessary to use different cost data in each case to present a consistent analysis.

The aircraft empty weight case used the broadest (and least accurate) measure of suite cost consisting of 100th unit, average last lot cost and estimated system costs. The estimated system costs distinguish this case from the other three cases. These costs were generated by analogy to like systems and the mean of their respective functional group. We are reasonably confident that no major biases were introduced by this procedure, since the percentage of estimated total suite cost due to our estimates was small.

Common to all four cases was the mixing of 100th unit and average last lot system costs. This is representative of the way that suites are procured, since a mix of old- and new-design equipment is selected on the basis of capability and availability. We expect future avionics suites to display the same sort of mix.

In the three cases using avionics characteristics, it was necessary to adjust the cost data to account for missing characteristics values. Thus the weight case includes all systems for which weight data were available, and the power and volume cases are similarly inclusive.

III. SUITE LEVEL COST ESTIMATING

This section considers the problem of making planning estimates for avionics suites in the absence of detailed technical data for the avionics. We approach this problem in two ways: The first assumes that only gross aircraft characteristics are available; the second assumes that the estimator has knowledge of the avionics suite characteristics. The rationale for using avionics characteristics is stronger, but information on aircraft characteristics would generally be available earlier in the planning process; thus both approaches may be useful.

Costs and technical data pertaining to the following discussion are contained in Appendix A. "Estimated Total Suite Cost," the dependent variable for the aircraft characteristic case, consists of 100th unit, average last lot, and roughly estimated system costs. In addition, the "Suite Cost by Weight," "Suite Cost by Volume," and "Suite Cost by Power" of the avionics characteristics cases are partial totals reflecting 100th unit and average last lot system costs without estimates of missing systems.

ESTIMATING WITH AIRCRAFT CHARACTERISTICS

Why should avionics suite costs be a function of combat aircraft characteristics? Because, among other reasons, the aircraft size constrains the amount of avionics onboard, and the aircraft operational environment and weapons determine suite functional requirements. Moreover, it can be argued that since aircraft costs increase with size, more and more expensive avionics are justified in the interests of overall cost effectiveness.

Explanatory Variables.

The aircraft characteristics and capabilities that we considered are listed in Table 2. A few comments are in order regarding these candidate explanatory variables.

The number of seats in an aircraft influences avionics costs in two opposite ways: (1) Two crew members require two sets of most displays and controls, thus increasing cost; (2) Two-seat aircraft require more airframe weight relative to the avionics carried, thus

Table 2

AIRCRAFT CHARACTERISTICS AND CAPABILITIES
FOR ESTIMATING AVIONICS SUITE COSTS

SIZE	ENVIRONMENT
Aircraft Empty Weight	Carrier Based
Number of Seats	
Aircraft Length (Volume Proxy)	ARMAMENT
	Radar Launch-Guided Missile
MISSION	
All-weather	TIME/TECHNOLOGY
Air to Air	Year of First Flight
Air to Ground	
Penetrating (Active ECM)	

decreasing the influence of aircraft empty weight on suite cost. The air-to-air and air-to-ground variables represent the principal mission of the aircraft; although some aircraft have both capabilities, no aircraft within the sample is given credit for both. Radar launch-guided air-to-air missiles are represented by Sparrow (F-4 and F-15) and Phoenix (F-14) in the sample; these missiles require aircraft radar assistance in reaching their targets as opposed to the infrared-seeking Sidewinder carried by other aircraft.

Data.

The complete data set for avionics suites is contained in Appendix A. For purposes of discussion, Fig. 1 shows the estimated total suite cost plotted against aircraft empty weight for the seventeen combat aircraft in the sample.

An immediate problem apparent in the plot is the vertical scatter associated with the multiple series aircraft (i.e., A-7s, F-4s, and F-111s). This points out a weakness of aircraft empty weight as a proxy for avionics cost, since any given airframe can accommodate vastly differing assortments of avionics.

The range of the scatter for the multiple series aircraft is an indication of the accuracy that can be attained in estimating suite cost from aircraft characteristics. It should also be noted that suites tend to get more expensive as subsequent models are produced, a trend that should be taken into account when estimating the total complement of some future aircraft series.

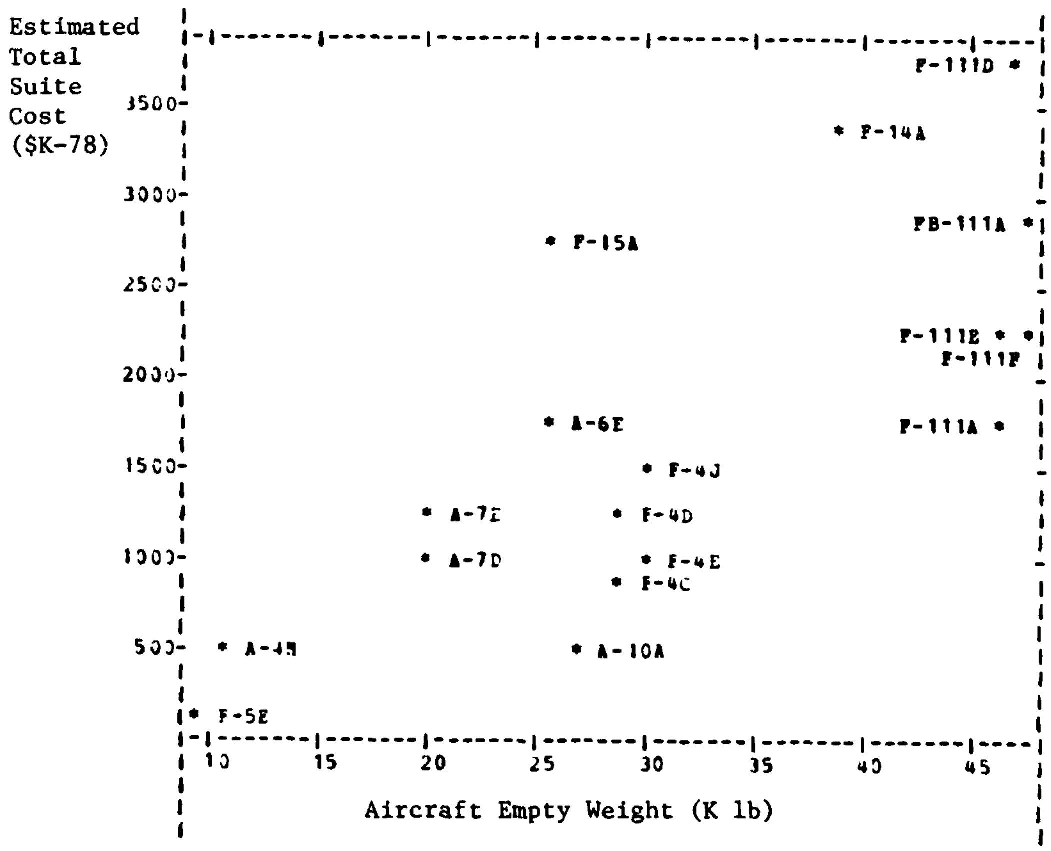

Fig. 1--Estimated total suite cost versus aircraft empty weight

We accommodate the vertical scatter problem by averaging the multimodel cost and weight data and using the midrange of the first flight dates. The average is treated as the best estimate for the series and is incorporated as a single data point without further weighting. Averaging serves to prevent overemphasis of a particular airframe, and the use of the midrange first flight date reflects the technological (and equipment configuration) growth across models. This treatment of the multiple series problem is at best a compromise, but it seems an appropriate way to combine these aircraft with a group of first (A-10A, F-14A, F-15) and last (A-6E, A-4M, F-5E) models.

Regression Analyses.

We obtained a statistically significant estimating model by regressing log aircraft empty weight, first flight date, and all-weather capability on log estimated total suite cost. Table 3 shows the resulting equation along with pertinent statistics, input data, predictions, and residuals.*

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*All regression analyses (e.g., Table 3) were of the "log-linear" form, that is, logarithms of dependent and independent (except dummy) variables are taken before linear regression is performed. When these logarithmic equations are transformed to the power forms displayed here, a bias is introduced. The error term of the equation was normally distributed prior to transformation, log-normally after. To correct for this bias, the constant term in the equation is multiplied by $e^{SEE^2/2}$, where SEE is the standard error of the estimate of the prediction equation. This results in the equation's being an unbiased estimator of the mean of the cost distribution. Subsequent to this adjustment the average standard error can be calculated as

$$\overline{SEE} = \frac{e^{SEE} - e^{-SEE}}{2}$$

This is a constant percentage error which approximates the dispersion about the adjusted estimator.

Table 3

REGRESSION EQUATION, DATA, AND RESULTS FOR
AIRCRAFT CHARACTERISTICS CASE

Equation[a]

$$\text{COST} = 1.38\ \text{WEIGHT}^{1.44}\ e^{(.14\ \text{FSTFLT} + 1.41\ \text{ALLWTHR})}$$

(.01) (.01) (.01)

Where:
- ALLWTHR = All weather capability (Yes=1/No=0)
- COST = Estimated total avionics suite cost ($K-78)
- FSTFLT = Aircraft first flight data minus 62
- WEIGHT = Aircraft empty weight (K-lbs)
- ( ) = Significance of regression coefficient (one-tailed t-test)

Statistics[b]

$R^2 = .99$ SEE = .14 F = 144, Significant at < 1%

Data and Results

Aircraft	WEIGHT	FSTFLT+62	ALLWTHR	Cost	COST Estimate[a]	Residual	|%|
A-4M	10.8K-1b	70	Yes	$480K-78	$533K-78	$-53K-78	11
A-6E	25.6	70	Yes	1695	1847	-152	8
A-7	19.8[c]	68	Yes	1122	964	158	14
A-10A	19.9	72	No	445	415	30	7
F-4	29.4[c]	65[d]	Yes	1176	1120	56	5
F-5E	9.6	72	No	135	145	-10	7
F-14A	38.9	70	Yes	3370	3374	-4	<1
F-15A	25.8	72	Yes	2750	2472	278	10
F-111	46.8[c]	67.5[d]	Yes	2559	3103	-544	21

[a]Adjusted for bias due to log-linear regression.

[b]Statistics based on logarithmic model form.
R^2 = coefficient of determination unadjusted for degrees of freedom.
SEE = standard error of the estimate of the prediction equation.
F = F-statistic specifying level of significance of equation.

[c]Average of models in sample.

[d]Midrange of models in sample.

Discussion

The logarithmic equation form provides a very good fit to the data. The fact that the coefficient of log aircraft empty weight is greater than one, reflecting a diseconomy of scale of suite costs relative to aircraft weight, is consistent with the notion that specialization occurs at the margin: All aircraft have radios but not all have inertial navigation sets.

All-weather Variable. According to our equation, an all-weather capability quadruples the cost of the avionics suite. This translates to suite costs of $594K-78* and $1700K-78 for all-weather versions of the F-5E and A-10A, respectively. Confidence placed in these estimates and in other differential estimates concerning all-weather capability should be guarded, since the F-5 and A-10 are the only non-all-weather aircraft in the sample.

First Flight Date (Time) Variable. Within the sample, time accounts for a 15-percent per year growth in suite cost. This is due to miniaturization of componentry and increased automation in design and manufacture, resulting in more functions from a given quantity of equipment and less cost per function but more cost per pound. Because mission requirements for combat aircraft are so demanding, suites tend to grow to fill the available space, resulting in more expensive suites.

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*The notation "$594K-78" means $594,000 fiscal year 1978 dollars.

We assessed the marginal effects of using first flight date and the F-15A--the newest aircraft in our sample--on the estimating equation; results are shown in Table 4.

Table 4

EVALUATING EFFECTS OF TIME VARIABLE
ON AIRCRAFT CHARACTERISTICS COST
ESTIMATING RELATIONSHIP

Sample	Equation Form	With Time?	R^2	SEE	F-15 Estimate	Percent Residual
With	Log	Yes	.99	.14	$2472K	10%
F-15	Log	No	.92	.34	1691	38%
Without	Log	Yes	.99	.14	2274	17%
F-15	Log	No	.96	.26	1509	45%

With the F-15A in the sample, we see that first flight date explains 7 percent of the total variance (the difference in R^2 for the two cases), which makes time seem relatively unimportant. When we consider the F-15A estimates, however, we see that the percent residual has more than tripled. Inasmuch as the F-15A is our best indicator of current technology, we were concerned that it might be an "outlier" in the sample, that is, exceptionally expensive. The second set of two equations summarized in Table 4 shows that time is an important variable even without the F-15 and that the F-15 is fairly well estimated (17-percent underestimate) by the aircraft empty weight, first flight date, all-weather variables equation based on the remaining eight observations.

Recommendations.

Successful use of the equation with its time variable depends on an appropriate evaluation of the technology involved. There are several approaches which can be taken in dealing with this technology assessment problem. The first would be to deal with the new aircraft "as if" it incorporated F-15A level technology. This would involve substituting "10"(72-62) for the first flight date and would result in the following equation:

$$COST = 5.60\ WEIGHT^{1.44}\ e^{1.41\ ALLWTHR}$$

Since this clearly underestimates the F-15A, an F-15A "technology year" of 1973.4 (11.4) can be calculated by solving the estimating relationships for FSTFLT given F-15A actual cost; an F-15A-benchmarked equation is obtained:

$$COST = 6.81\ WEIGHT^{1.44}\ e^{1.41\ ALLWTHR}$$

Pushing the constant term beyond this level requires careful consideration of many subjects. Obviously the trends in avionics technology are most important, and analogies drawn from, for instance, the F-4, F-15, and the planned aircraft for which an estimate is required may offer some hint at the years of technology progress expected.

Other factors, usually apprised judgmentally, are likely to have important implications for avionics cost estimating, however. These include such topics as suites that are limited by cost constraints rather than performance, quantity-quality tradeoffs, future threat assessments, offensive versus defensive avionics technologies, and the likelihood that the avionics industry will change from a technology orientation toward producibility.

Of course, an estimating equation essentially reflects the data within the sample from which it is derived. Aircraft empty weight extrapolations are uncertain at best and extrapolations based on time are even more prone to unsatisfactory outcomes. And while most future aircraft will fall within the weight range of our sample, none will fall within the time range.

Care must also be taken when comparing aircraft concepts. The equation in Table 3 presumes a relationship between aircraft size and the amount of avionics that would be installed. When planning aircraft systems, less aircraft weight would imply less avionics cost and less avionics capability. If equal capability between different sized aircraft is assumed, an adjustment would be required to make the suite of the smaller aircraft at least as expensive as the larger aircraft (probably more so because of miniaturization and integration problems).

ESTIMATING WITH AVIONICS CHARACTERISTICS

Our results using avionics suite technical characteristics are very similar to those obtained with aircraft characteristics. Here we discuss the data and adjustments before developing cost estimating relationships based on the weight, volume, and power of the avionics suite. We present relationships for all three variables because our interviews with cost estimators indicated a need for them. In addition, they provide an opportunity for cross-correlation and comparison of estimates.

Data.

Table 5 lists cost and technical data for the seventeen aircraft in our sample. Three different costs are shown for each aircraft, corresponding to the matched set of cost and technical characteristics for the avionics systems within each suite. Avionics systems with missing values were eliminated in Table 5. The missing values appear to be randomly distributed and there should be no bias in estimating equations derived from these data sets.

Table 5

AVIONICS SUITE COST AND TECHNICAL DATA

	Weight		Volume		Power	
Aircraft	Pounds	Cost[a]	In.^{3}	Cost[a]	VA[b]	Cost[a]
A-4M (25)[c]	839.9(23)[d]	$462.5	27554(18)[d]	$378.2	6937(14)[d]	$332.7
A-6E (29)	1735.1(25)	1674.8	34654(18)	853.3	6368(14)	679.9
A-7D (23)	1120.7(18)	844.3	43298(13)	696.4	10541 (7)	465.5
A-7E (29)	1439.9(25)	1056.5	51298(17)	889.9	8300(12)	538.9
A-10A (17)	583.7(15)	369.9	14586(14)	288.4	3070(14)	288.4
F-4C (15)	1803.0(11)	646.2	48838(10)	538.9	11991 (9)	524.8
F-4D (19)	1741.0(13)	729.5	51424(12)	622.2	8237 (8)	393.9
F-4E (17)	1247.0(11)	721.8	41314(10)	690.7	5237 (8)	572.6
F-4J (23)	2249.4(23)	1523.8	59929(16)	1397.7	19369(11)	1066.2
F-5E (8)	168.7 (5)	100.8	7673 (5)	100.8	1030 (4)	94.4
F-14A (35)	2198.8(29)	2579.5	64841(24)	2519.4	29401(18)	2050.2
F-15A (33)	1579.9(24)	2488.0	50820(24)	2488.0	22497(23)	2486.6
F-111A (17)	1774.0(15)	1669.1	53547(12)	1382.9	5621 (9)	732.9
F-111D (21)	2354.0(18)	3563.6	55503(13)	1674.2	13529(11)	1939.3
F-111E (18)	2174.0(16)	2112.3	67371(13)	1826.1	8926(10)	755.4
F-111F (18)	2057.0(16)	2148.0	64676(13)	1861.8	8926(10)	722.5
FB-111A(22)	2503.0(20)	2737.9	81871(16)	2252.9	7856(10)	904.0

[a]Thousands of FY78 dollars.

[b]Input power requirement of the avionics suite in volt-amperes.

[c]Number of systems in the total suite.

[d]Number of systems for which data were available.

Adjustments

Unlike the aircraft characteristic case, we did not find it necessary here to average observations for multiseries aircraft. The suites of the multiseries aircraft are sufficiently different from one another that their costs may reasonably be assumed to reflect cost differences as a function of size.

Regression Analysis

The approach taken with the avionics explanatory variables matches that taken with the aircraft explanatory variables. Only the size variables of Table 2 change in the cases that follow. Because of the correlation among the variables, no equations were developed using more than one size variable. The three cases that follow are sequenced in order of descending completeness in the data base: weight, volume, then power. The results for the power variable case should be given less consideration thán the other two cases because of the excessive sparseness of the power variable data set.

Estimating with Avionics Suite Weight

Figure 2 shows the plot of suite cost versus suite weight for the aircraft in the sample. An increasing curvilinear trend (indicating that cost per pound increases with weight) with significant scatter can be seen. Of particular interest is the placement of the F-4C, D, J and the F-15A; they deviate from the norm in a way that suggests a time influence.

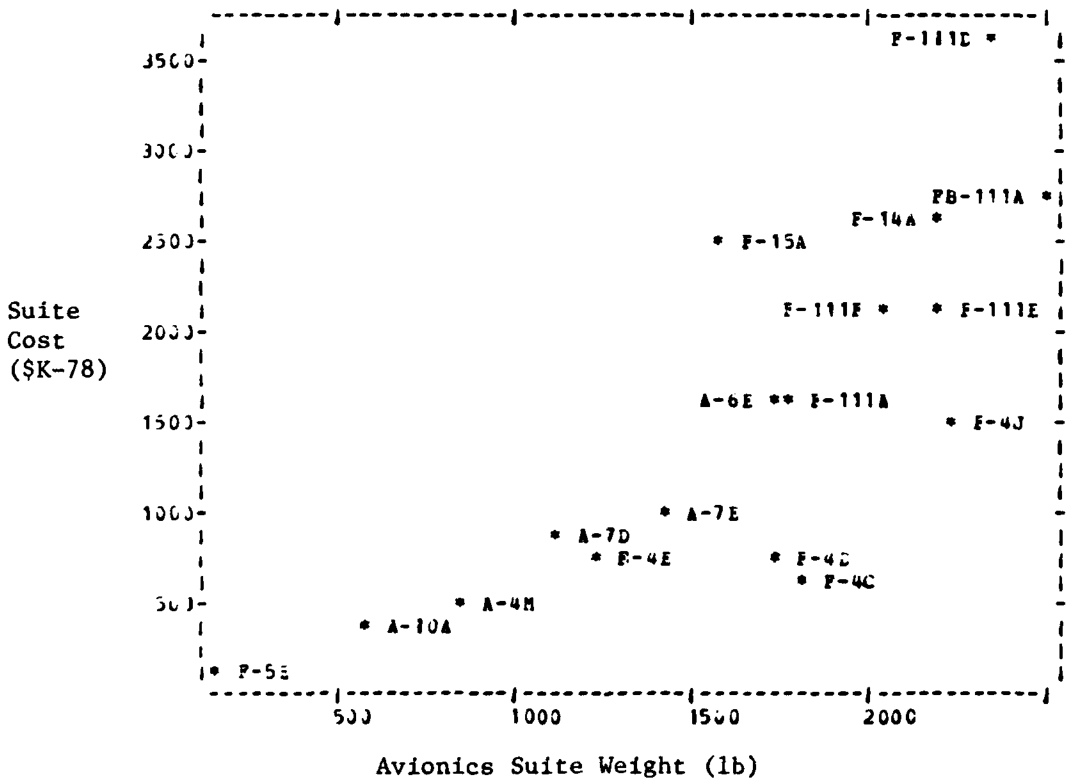

Fig.2--Suite cost versus avionics suite weight

Figure 3 directly considers the influence of time. There we see cost per pound for the suites plotted against first flight date. Cost per pound should increase with suite weight (the trend shown in Fig. 2), but we can still observe a significant relationship between cost per pound and time for the majority of the sample. The distant points in the latter, however, are the most interesting cases.

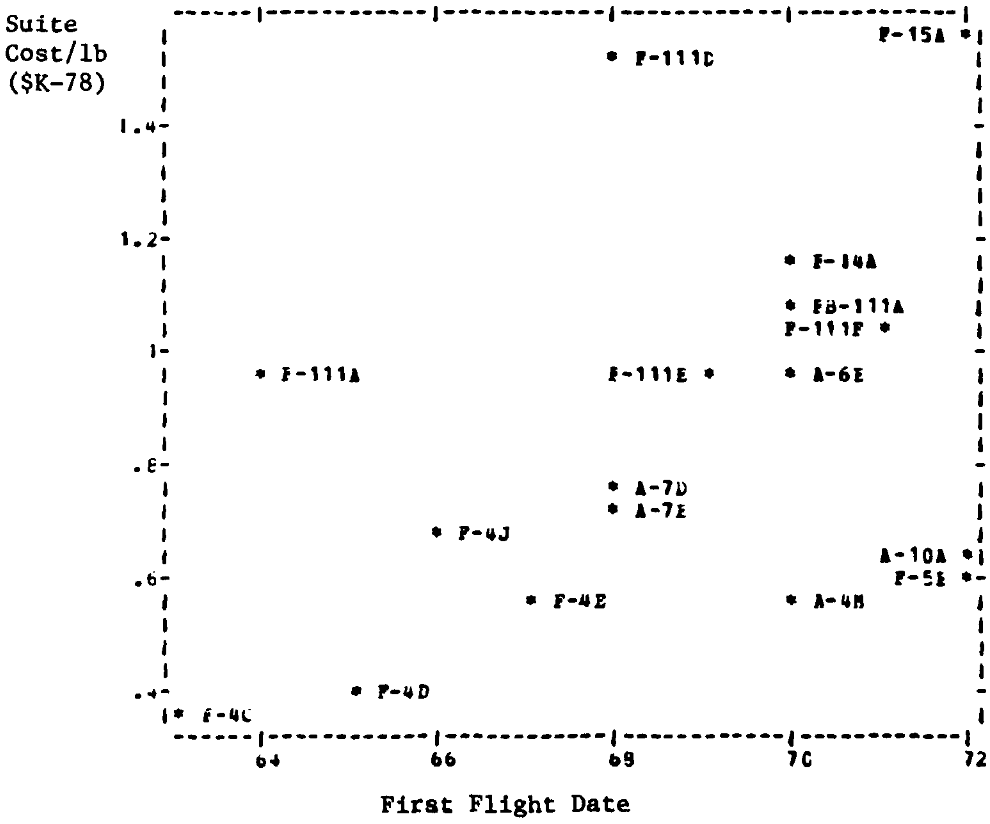

Fig. 3--Avionics suite cost per pound versus first flight date

The F-111A and D, even after accounting for their relatively heavy suites, appear to have been built "before their time." Inasmuch as they were both technically ambitious and troubled by development problems, their placement on the plot is understandable. Of greater importance to the regression analysis. however, is whether they are representative of future avionics suite acquisition or merely represent atypical cost outcomes. We first include and then exclude the F-111A and D to determine their overall affect on our analysis.

The A-10A and F-5E are explained both by their light-weight suites and their lack of all-weather capabilities. The A-4M, however, is less well explained. Two factors seem to contribute to its low cost per pound. These are minimal all-weather capability (it does not carry an inertial navigation system) and inheritance from earlier A-4 models. Rather than trying to adjust the A-4M first flight date or developing another measure of mission capability (see Table 2), we retained the A-4M as given, to represent the diversity of suite composition.

Regression Analysis. Based on the above review of the data, log-cost was regressed on log-weight, first flight date, and all-weather capability. All-weather capability proved to be insignificant, probably because lack of the capability was implied by the suite weight. The adjusted regression equation, statistics, data, and results are shown in Table 6. There we see that a doubling of suite weight will increase cost by a 2-2/3 multiple and that suite cost has been increasing at about 12 percent per year (for a constant suite weight).

Table 6

REGRESSION EQUATION, DATA, AND RESULTS FOR AVIONICS SUITE WEIGHT CASE

Equation

$$\text{COST} = .019\ \text{WEIGHT}^{\underset{(.01)}{1.42}}\ e^{\underset{(.01)}{.11\ \text{FSTFLT}}}$$

Where: COST = avionics suite cost adjusted for weight data ($K-78)

FSTFLT = aircraft first flight date minus 62

WEIGHT = avionics suite weight (lb)

Statistics[a]

R^2 = .92 SEE = .28 F = 78, Significant at < 1%

Data and Results

Aircraft	WEIGHT	FSTFLT +62	Cost	COST Estimate	Residual	|%|
A-4M	840	70	$ 462K-78	$651K-78	$ -189K-78	41
A-6E	1735	70	1675	1823	-148	9
A-7D	1121	68	844	787	57	7
A-7E	1440	68	1056	1123	- 67	6
A-10A	584	72	370	484	-114	31
F-4C	1803	63	646	891	-245	38
F-4D	1741	65	730	1057	-327	45
F-4E	1247	67	722	820	- 98	14
F-4J	2249	66	1524	1697	-173	11
F-5E	169	72	101	83	18	18
F-14A	2199	70	2580	2552	28	1
F-15A	1580	72	2488	1989	499	20
F-111A	1774	64	1669	972	697	42
F-111D	2354	68	3564	2256	1308	37
F-111E	2174	69	2112	2249	-137	7
F-111F	2057	71	2148	2591	-443	21
FB-111A	2503	70	2738	3067	-329	12

[a]Based on logarithmic model form.

The statistics of the equation show significance in all aspects, but are less impressive than those of the aircraft characteristic case. This is most likely due to the averaging that was done in the aircraft case. Percentage residuals exceed 25 percent for six aircraft:

A-4M	-38 percent
A-10A	-28
F-4C	-36
F-4D	-42
F-111A	43
F-111D	38

The F-111A and D and A-4M errors are consistent with our previous discussion of those suites. In the case of the F-4C and D we suspect that their use of a significant proportion of vacuum-tube technology and excessive sparseness of the data sets may account for some portion or these errors. Of course, the presence of the F-111A and D in the sample does not help to explain the costs of these earlier, less expensive suites of the F-4C and D. In the case of the A-10A, our overestimate is probably due to the A-10's use of mature avionics technology, which would make the first flight data a poor proxy for a technology date.

Because of our concern with the F-111A and D suite costs, we refit the equation on 15 aircraft with the following results:

$$\text{COST} = .016\ \text{WEIGHT}^{1.40}\ e^{.14\ \text{FSTFLT}}$$

The weight exponent is slightly smaller and the effect of time changes from 12 percent to 15 percent per year. The residuals pattern also is different: the A-4M is slightly better, the A-10A is slightly worse, and the F-4C and D are much better. The net effect of modifying the sample is to emphasize the effect of the time variable. Because it is difficult to establish the proper technology date for future aircraft, we prefer the equation based on the full sample.

Recommendations. The relationships obtained with avionics characteristics should be treated similarly to those obtained in the aircraft characteristics case. If the user believes that the F-15A is the most appropriate technological benchmark for estimating future combat avionics suite costs, the estimating equation can be pinned to that aircraft. Either first flight date or cost may be fixed. Or the equation may be used as is with proper analysis and selection of the first flight date as related to the status of avionics technology. Equations for the F-15A related cases are as follows:

Time fixed: $COST = .057\ WEIGHT^{1.42}$ (using F-15 FFD = 1972)

Cost fixed: $COST = .071\ WEIGHT^{1.42}$ (technology year = 1974)

Estimating with Avionics Suite-Volume

Our approach here (and with respect to suite-power) is strictly analogous to the suite-weight case. Figure 4 shows the plot of suite cost versus suite-volume. Comparison to the weight plot shows a similarity in pattern, but with much changing of position for the individual suites. Regression of log-cost on log-volume and first flight produced the estimating relationship shown with the applicable statistics, data, and results in Table 7.

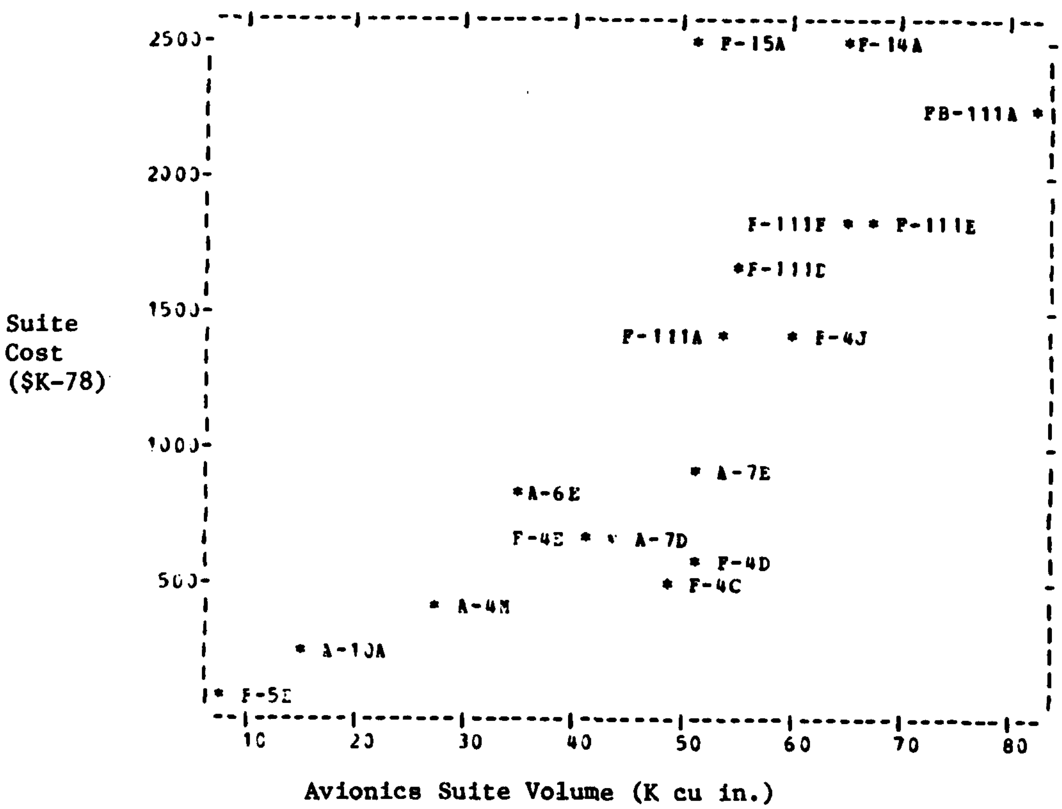

Fig. 4--Suite cost versus avionics suite volume

Table 7

REGRESSION EQUATION, DATA, AND RESULTS FOR
AVIONICS SUITE VOLUME CASE

Equation

$$\text{COST} = \underset{(.01)}{\text{VOLUME}^{1.52}}\ \underset{(.01)}{e^{.11\ \text{FSTFLT}}}$$

Where: COST = estimated suite cost adjusted for volume data (K-78)
VOLUME = avionics suite volume (K-in.^{3})
FSTFLT = aircraft first flight data minus 62

Statistics[a]

$R^2 = .91$ SEE = .28   F = 72,   Significant at < 1%

Data and Results

Aircraft	VOLUME	FSTFLT +62	Cost	COST Estimated	Residual	|%|
A-4M	27.6 K-in.^{3}	70	$ 378K-78	$ 590 K-78	$- 12 K-78	56
A-6E	34.7	70	853	836	17	2
A-7D	43.3	68	696	939	-243	35
A-7E	51.3	68	890	1215	-325	37
A-10A	14.6	72	288	279	9	3
F-4C	48.8	63	539	650	-111	21
F-4D	51.4	65	622	876	-254	41
F-4E	41.3	67	691	783	-92	13
F-4J	59.9	66	1398	1234	164	12
F-5E	7.7	72	101	106	-5	5
F-14A	64.8	70	2519	2160	359	14
F-15A	50.8	72	2488	1859	629	25
F-111A	53.5	64	1383	834	549	40
F-111D	55.5	68	1674	1370	304	18
F-111E	67.4	69	1826	2054	-228	12
F-111F	64.7	71	1862	2405	-543	29
FB-111A	81.9	70	2253	3083	-830	37

[a]Based on logarithmic model form.

In comparing the weight and volume cases, we see similar statistics and precision. There is some movement in error by aircraft (e.g., the A-10A improves while the A-7s worsen), but the general level of precision remains about the same. In particular, the percentage error for the F-15A only increases by 5 percent (20 percent versus 25 percent).

Recommendations. As before, care must be taken in applying the time variable. The equation forms for F-15 time- and cost-constrained estimators are as follows:

Time fixed: $COST = 4.75\ VOLUME^{1.52}$

Cost fixed: $COST = 6.32\ VOLUME^{1.52}$
(Technology year = 74.6)

Estimating with Avionics Suite Power

As noted before, data for the power variable are very sparse for many of the suites in our sample and the following results must be viewed with caution. Figure 5 contains a plot of the data. The scatter is quite different from that seen for weight and volume, especially regarding evidence of technological (time) effects. The plot confirms that power is a measure of size and hence cost, but the dispersion is large. We proceeded with regression analysis under the assumption that the errors in the data were contributing to dispersion without bias; that is, the regression equation would be a valid estimator even if its statistics were poor.

Regression Analysis. Table 8 contains the equation, statistics, data, and results for the suite-power case. The mean of the absolute percent residuals is 35 percent, much larger than the previous cases but perhaps acceptable for confirming planning estimates. The important thing to note is that the time variable is not included; it was significant at only the 30-percent level. The power exponent also indicates economies of scale, contrary to the

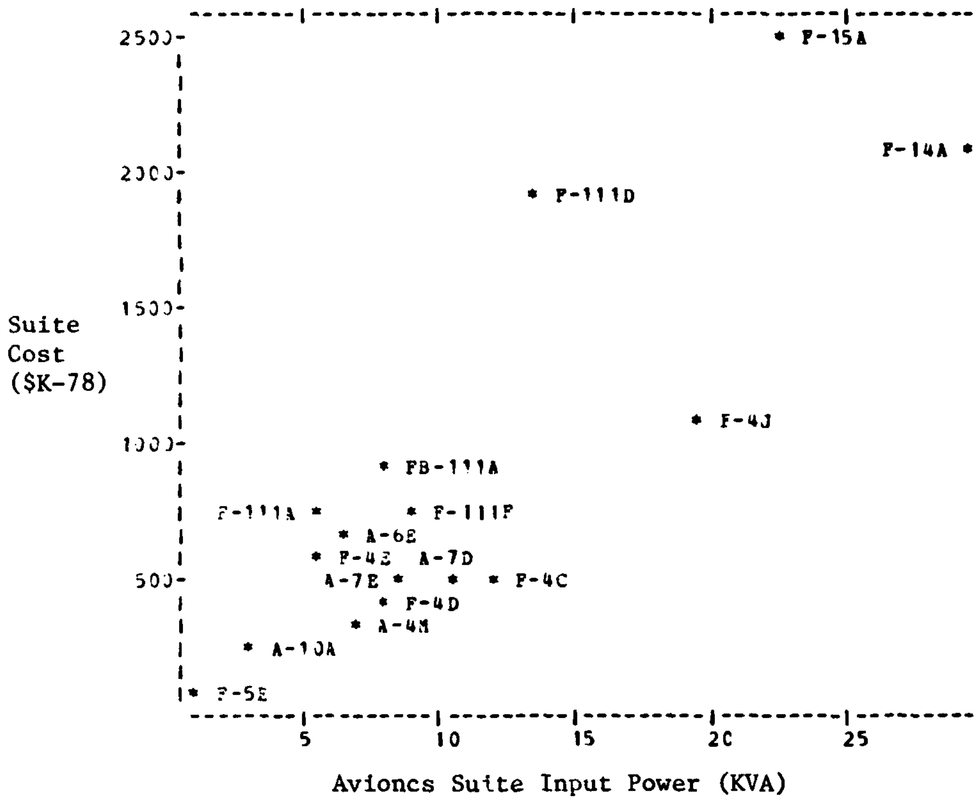

Fig. 5--Suite cost versus avionics suite power

weight and volume cases. This is most probably a reflection of the differing power consumption requirements of the various types of avionics equipments, especially the major emitters, radar, and active electronic countermeasures. For these, power output can exponentially increase with weight, thus explaining the reversal in scale economies.

In the absence of complete suite data it is difficult to test the consistency of the three estimators. However, the parameters of the power equation are very significant, and the relationship should not be dismissed out of hand.

Table 8

REGRESSION EQUATION, DATA, AND RESULTS FOR
AVIONICS SUITE POWER CASE

Equation

$$\text{COST} = 107.66\ \underset{(.01)}{\text{POWER}^{.89}}$$

Where: COST = avionics suite cost adjusted for power data ($K-78)
POWER = sum of system power requirements (kilovoltamperes)

Statistics[a]

$R^2 = .77$ SEE = .40 F = 49, Significant at < 1%

Data and Results

Aircraft	POWER	Cost	COST Estimate	Residual	|%|
A-4M	6.9 KVA	$333K-78	$601K-78	-$268K-78	80
A-6E	6.4	680	562	118	17
A-7D	10.5	466	873	-407	87
A-7E	8.3	539	708	-169	31
A-10A	3.1	288	295	-7	2
F-4C	12.0	525	983	-458	87
F-4D	8.2	394	700	-306	78
F-4E	5.3	573	475	98	17
F-4J	19.4	1066	1507	-441	41
F-5E	1.0	94	108	-14	15
F-14A	29.4	2050	2182	-132	6
F-15A	22.5	2487	1720	767	31
F-111A	5.6	733	499	234	32
F-111D	13.5	1939	1092	847	44
F-111E	8.9	755	753	2	1
F-111F	8.9	722	753	-31	4
FB-111A	7.9	904	678	226	25

[a]Based on logarithmic model form.

IV. SYSTEM LEVEL COST ESTIMATING

In this section we address cost estimating at the system (or "AN" or "black box") level. Technical, descriptive, and manufacturer's data for the systems in our sample are given in Appendix B. Cost data have been withheld because of proprietary considerations.

Our objective was to assess the suitability of easily obtainable technical variables for cost estimating relationships. As such, with one exception (the radar group), we used all the available data. That is, we did not eliminate "outliers" in the samples as is often done when there exist strong expectations of a particular equation form. Rather we fitted log-linear equation forms to the data and report all results, regardless of significance, in order to fully express the information in the data base.

In the following discussion, we detail our approach, present results for samples consisting of all systems and 11 functional groups, and discuss these results in comparison with available cost-per-pound data.

APPROACH

At the system level, we deal only with systems for which cost data could be calculated at the 100th unit; that is, systems for which we had several lot quantities and costs (comparable information from the manufacturer) and could estimate the learning curve. On systems for which we had only one lot average, presumably the last lot, we chose not to artificially adjust the data through the use of an assumed total quantity and average learning curve. The variation in these measures was found to be large, so that error introduced by the adjustment would produce misleading results. For example, for the entire data base the average learning curve is 92.1 percent, with a standard deviation (σ) of 9.7 percent. At the 100th unit the one-σ adjustment ranges from 27.6 percent to 112.6 percent of the first unit cost. This is comparable to 57.9 percent of the first unit cost at the mean learning curve value. Only in the case of the Optical Systems functional group (discussed below) did we make a gross adjustment of last lot average data (in the interest of completeness).

Cases

We have 12 separate cases for analysis at the system level. These consist of all equipment and the following 11 functional subgroups:

Active Electronic Countermeasures

Computers

Displays

Electromechanical Devices

Inertial Systems

Optical Systems

Passive Electronic Countermeasures

Radars

Radar Navigation

Radio Communication

Radio Navigation

In Appendix B, two other groups are listed which are not included here: Power Management (sample size too small to permit analysis) and Miscellaneous (no basis for analysis). We selected functional groups in line with our expectations about cost. The nature and function of major componentry within each system determined the group assignment. Thus, the Optical Systems group contains systems ranging from sights to infrared sensors to laser designators, while the Inertial Systems group ranges from simple attitude reference indicators to complete inertial navigation systems. Our intent was to establish groups, such that the size variables could be expected to reflect the cost of a homogeneous type of componentry. As a result these groups are functional in an equipment sense rather than in an aircraft mission sense (e.g., "navigation" or "target acquisition").

Explanatory Variables

The size variables used here are similar to those in the suite analyses: weight, volume, and power. More detailed measures, such as piece-part count, were not available to us and do not fit our objective of providing an estimating capability useable early in system planning. We did not, however, use time as a proxy for technology in analyzing the systems. As noted in Section II, we used technology categories to try to isolate cost differences due to technology. The systems were assigned to "Vacuum Tube," "Solid State," or "Integrated Circuit" technology groups. This categorization is not complete, and many systems built with components from different categories could arguably be assigned to more than one of the above groups. We preferred to restrict the categories to three and assign systems as best we could rather than increase the number of dummy variables used on our already limited samples. A major advantage in using technological categories is the avoidance of the difficulties associated with using time as a variable.

Regression Analysis Format

In each of the 12 cases we present up to six regressions: three for the size variables alone and three with technology added. The equation forms, consistent with the expectation of economies of scale with respect to size, were logarithmic-linear in cost and size; for the technology forms two of the three dummy variables were included as linear additions. A successful technology regression generates three parallel lines on logarithmic graph paper, one for each technology level.

RESULTS

In the following discussion we describe the sample and examine the regression results for the 12 cases previously defined. We also describe the Power Management group. All regression results are included, regardless of their significance, in order to more completely describe the data; thus the parameter and equation significance should be carefully noted.

In Tables 9 through 20, the following information applies:

- Weight is in pounds.
- Volume is in cubic inches.
- Input power is in voltamperes.
- SOLID is the dummy variable for Solid State circuitry (yes = 1, no = 0).

- INTGRTD is the dummy variable for integrated circuitry (yes = 1, no = 0)
- Cost is in thousands of fiscal year 1978 dollars.
- R^2 is the coefficient of determination of the logarithmic estimate.
- SEE is the standard error of the logarithmic estimate.
- The equation significance level results from evaluation of the F-statistic for logarithmic estimates.
- Parameter significance level is shown in parentheses below the estimate and was derived from a one-tailed t-test.
- Conversion to power form includes the adjustment $SEE^2/2$ added to the log constant term.

All Systems Case

Table 9 displays the six equations generated for the All Systems case. All six equations are significant at the 1-percent level, and all reflect economies of scale relative to the size variable. The addition of the technology variables affects the constant and size exponent in each case, but the technology coefficients are not as significant in the weight and volume cases. The effect of the technology variables ranges from a 43-percent increase in the case of weight and solid state to a tripling of cost in the case of volume and integrated circuitry. The standard errors shown are quite large; the averages range from 84 percent to 107 percent. These estimators have limited utility, except as possible independent checks of estimates prepared by other means.

Table 9

ALL SYSTEMS CASE REGRESSION RESULTS

Equation[b]	Adjusted[a] R^2	SEE	Significance	Sample Size
$1.33\ \text{Weight}^{.97}$ (.01)	.72	.81	.01	111
$1.09\ \text{Weight}^{.94}\ e^{(.36\text{SOLID} + .76\text{INTGRTD})}$ (.01) (.10) (.01)	.73	.76	.01	80
$.20\ \text{Volume}^{.77}$ (.01)	.66	.85	.01	97
$.11\ \text{Volume}^{.78}\ e^{(.53\text{SOLID} + 1.10\text{INTGRTD})}$ (.01) (.05) (.01)	.67	.82	.01	73
$1.83\ \text{Power}^{.66}$ (.01)	.59	.93	.01	84
$.85\ \text{Power}^{.69}\ e^{(.68\text{SOLID} + .79\text{INTGRTD})}$ (.01) (.01) (.01)	.70	.78	.01	63

[a]In all systems level equations:
Weight is in pounds.
Volume is in cubic inches.
Power is in voltamperes.

[b]Adjusted for degrees of freedom.

The results obtained here led us to conclude that all avionics equipment is not homogeneous and that better results might be obtained by grouping equipment in accordance with function, as explained below.

Active Electronic Countermeasures (ECM) Case

Active ECM systems deliberately prevent or reduce an opponent's effective use of the electromagnetic spectrum by jamming and deception. Functions may include detection, processing, and wave forming; they always include signal emission. A more complete understanding of our definition of this group (and the other groups) can be obtained by reviewing the group members listed in Appendix B.

Table 10 lists our regression results for Active ECM. Shown here are the six regression equations and their statistics, followed by a residual chart for the weight-only equation. The residuals are shown by a "W" under broad percentage categories with positive (+) and negative (-) signs indicated. The more "Ws" to the left of the chart, the better the fit of the equation. Only the power-technology case is not significant at the 10-percent level. All three technology cases produced insignificant coefficients. The improvement in R^2 and SEE is probably due to the increase in the number of independent variables and should not be considered important. In the three size cases, weight is linear (exponent = 1.0), while volume shows increasing returns to scale (but exponent nearly 1.0) and power shows marked decreasing returns. That power should be substantially different from weight and volume is reasonable, since Active ECM equipment relies on large amounts of power for many requirments. The standard error results tend to show that this case reflects the benefits of homogeneity. Average error here ranges from 64 percent (power) to 68 percent (weight) for the size-only cases.

<u>Computers</u>

We viewed a computer as an input-output device which produces processed information. As such, we included analog and digital machines within our sample. On the surface, this seems to contradict our goal of homogeneity, but there was no evidence in the data to distinguish the one type from the other, and the increased sample size was beneficial to the analysis.

Table 10

ACTIVE ELECTRONIC COUNTERMEASURES CASE REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Signif-icance[a]	Sample Size
$.82\ \text{Weight}$ (.01)	.49	.64	.05	10
$.76\ \text{Weight}^{.92}\ e^{(.27\text{SOLID} + .80\text{INTGRTD})}$ (.05) (-) (.10)	.51	.60	.10	9
$.02\ \text{Volume}^{1.02}$ (.01)	.50	.63	.05	10
$.0003\ \text{Volume}^{1.47}\ e^{(-.50\text{SOLID} + .88\text{INTGRTD})}$ (.05) (-) (.05)	.69	.48	.05	9
$6.55\ \text{Power}^{.48}$ (.05)	.55	.60	.05	8
$5.39\ \text{Power}^{.49}\ e^{(.61\text{SOLID} - .16\text{INTGRTD})}$ (.05) (-) (-)	.56	.59	-	8

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages[b]				
	0 - 25	25 - 50	50 - 75	75 - 100	100+
ALQ-41					-W
ALQ-51				- W	
ALQ-51A		-W			
ALQ-88					-W
ALQ-92	+W				
ALQ-94		+W			
ALQ-100		-W			
ALQ-126		+W			
ALQ-128	+W				
ALQ-135		+W			

[a] A significance level designation of "-" indicates greater than 10 percent.
[b] Residual percentages calculated as ([actual cost minus estimated cost]/actual cost) x 100. Proprietary reasons mandated the use of ranges rather than actual results. A "+" indicates a positive value and a "-" notes a negative value.

Table 11 shows the regression results for computers. All equations and parameters were significant. Average standard errors range from 49 percent (power-technology) to 89 percent (volume and power). The technology variables greatly improve each of the three size cases.

Table 11

COMPUTERS CASE REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Signif-icance	Sample Size
$2.21\ \text{Weight}^{.93}$ $(.01)$	.46	.75	.01	17
$.17\ \text{Weight}^{1.22}\, e^{(1.45\text{SOLID} + 2.11\text{INTGRTD})}$ $(.01)\ (.01)\ (.01)$	.72	.52	.01	16
$.13\ \text{Volume}^{.91}$ $(.01)$	.42	.80	.01	14
$.02\ \text{Volume}^{.97}\, e^{(1.61\text{SOLID} + 2.10\text{INTGRTD})}$ $(.01)\ (.01)\ (.01)$	.68	.56	.01	13
$6.69\ \text{Power}^{.50}$ $(.05)$	.23	.80	.05	14
$.29\ \text{Power}^{.80}\, e^{(1.67\text{SOLID} + 1.89\text{INTGRTD})}$ $(.01)\ (.01)\ (.01)$	.70	.47	.01	13

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
AJB-3A					-W
AJB-7					-W
APA-157					-W
ASK-6			-W		
ASN-39			-W		
ASN-41				-W	
SSN-91	+W				
ASQ-61			+W		
ASQ-91		-W			
ASQ-133		-W			
ASQ-155	+W				
AWG-9COMP		+W			
AYK-6		+W			
CP-1005A					-W
CP-1035A	-W				
CP-1075/AYK	+W				
CSDC			+W		

It is interesting to note how the size exponents increase when technology is controlled for. In the weight case, the addition of technology generates marked increasing returns to scale relative to weight. The reason for this may be found in the ratio of support componentry (such as cabinetry and power supplies) to computing componentry as the system grows larger. It is reasonable to expect that the cheaper support componentry could support many levels of computing componentry, thus explaining the increasing returns.

Displays

In this group, we include devices designed to convert electronic data for visual display to the aircrew. Examples include head-up displays and horizontal situation indicators.

Table 12 displays the regression results for the Displays group. None of the technology equations were significant at the 10-percent level. Missing values in the technology data were a major reason for this (note the decreases in sample size). However, the size-only equations produced reasonably good results. The average standard error ranges from 36 percent to 56 percent, indicating that the affect of technology is not too great within this group.

Table 12

DISPLAYS CASE REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Significance	Sample Size
$1.20\ \text{Weight}^{1.01}$ $(.01)$	.89	.35	.01	12
$1.95\ \text{Weight}^{.98}\ e^{(-.35\text{SOLID} - .23\text{INTGRTD})}$ $(.05)\ (-)\ (-)$	.83	.51	-	6
$.13\ \text{Volume}^{.83}$ $(.01)$	.87	.41	.01	11
$.05\ \text{Volume}^{.96}\ e^{(.02\text{SOLID} + .25\text{INTGRTD})}$ $(.05)\ (-)\ (-)$	.96	.28	-	5
$1.25\ \text{Power}^{.70}$ $(.01)$	.79	.53	.01	10
$.20\ \text{Power}^{1.03}\ e^{(.01\text{SOLID} + 1.24\text{INTGRTD})}$ $(.05)\ (-)\ (-)$	.96	.27	-	5

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
AJN-18	-W				
ARU-39/A	-W				
ASA-79	+W				
ASN-99					-W
AVA-1		+W			
AVA-12	+W				
AVQ-20	+W				
C-9011	+W				
Head-Up DSPL			-W		
ID-1744A	+W				
OD-60/A	-W				
TV Monitor		-W			

Electromechanical Devices

This group is primarily composed of chaff/flare dispensers and weapons controls. An emphasis on servomechanisms and loadbearing members sets this equipment apart from other avionics systems.

Table 13 displays the results of three size-only regressions. The samples were too small for the size-technology formats. We note that the results for the power equation are relatively good, while the weight equation is especially poor. This is explained if we can assume that input power predicts the amount of relatively expensive electromechanical componentry in a system, while the pure mechanical componentry, cheaper but heavier, accounts for a small part of system cost. A review of the data, especially the contrast between weapons controls and flare/chaff dispensers, supports these assumptions.

In summary, power requirements best predict the cost of electromechanical systems, apparently because weight (and volume) are subject to inexpensive, but nonetheless major, changes.

Inertial Systems

Gyroscopic componentry is the unifying thread in this group. Inertial navigation systems make up most of the group, but attitude reference equipment is included as well. The functions performed include inertial sensing of acceleration and attitude changes, coupled with electronic transducers and processers to calculate navigation and position information. We were not always able to separate the computer used in inertial navigation from the other equipment. We believe, however, that this partial mixing of groups does not bias the sample significantly.

Table 13

ELECTROMECHANICAL DEVICES CASE
REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Signif-icance	Sample Size
$.28\ \text{Weight}^{1.35}$ (.10)	.26	1.20	-	6
$.0004\ \text{Volume}^{1.57}$ (.05)	.56	.92	.10	5
$.92\ \text{Power}^{.79}$ (.01)	.83	.56	.05	5

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
ALE-18					-W
ALE-29					-W
AWE-1		-W			
AWG-15	-W				
AWG-17		+W			
AWG-20	-W				

Table 14 shows our results for five of the six equation types; there were insufficient degrees of freedom in the power-technology case. The most significant results can be seen in the weight-technology and power cases, but the small sample sizes diminish their credibility. In the volume-technology case, the marginal significance of the parameters and equation brings R^2 and SEE values into question. The expononents are also not credible, and it can be assumed that these equations appear to have no estimating utility.

Table 14

INERTIAL SYSTEMS CASE REGRESSION RESULTS

Equation	Adjusted R^2	SEE	Significance	Sample Size
$1.10\ \text{Weight}^{\underset{(.01)}{1.15}}$	.49	.72	.01	11
$.001\ \text{Weight}^{\underset{(.01)}{2.49}}\ e^{(\underset{(.05)}{.42}\text{SOLID} + \underset{(.01)}{1.85}\text{INTGRTD})}$	.99+	.06	.01	6
$.11\ \text{Volume}^{\underset{(.01)}{.91}}$	.57	.61	.05	9
$.0004\ \text{Volume}^{\underset{(.05)}{1.49}}\ e^{(\underset{(.05)}{1.11}\text{SOLID} + \underset{(.05)}{1.57}\text{INTGRTD})}$	.99	.11	.10	5
$.02\ \text{Power}^{\underset{(.01)}{1.61}}$	.96	.17	.05	4

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
AJN-16			+W		
ASN-31	-W				
ASN-48				-W	
ASN-56			-W		
ASN-63				-W	
ASN-70					-W
ASN-90			-W		
ASN-108		-W			
ASN-109		+W			
CN-1377/AWG		+W			
LSI-6000A				-W	

Optical Systems

This group is characterized by a dependence on optical componentry and includes optical sights, infrared detectors, and laser designators. Sixteen systems are classified in this group, but a 100th unit cost could be calculated for only two of these systems. In order to present some indication of optical system costs, we adjusted the data.

Our adjustment procedure is based on the entire system-level data base and assumes that last-lot-average costs (unused elsewhere at the system level) tend to differ from 100th unit costs due entirely to their unit number. Thus, last-lot-average costs taken at the 50th unit would be above the trend relative to weight of the 100th unit costs, while last-lot-average costs taken beyond the 100th unit would be below the trend. The proper adjustment, then, was to multiply each last-lot-average cost by the quotient of the 100th unit cost versus weight regression and the last-lot-average cost versus weight regression. The data for the optical group was extracted from this adjusted set of last-lot-average costs. Our decision to restrict this procedure to the Optical Systems group, where it was needed to obtain any results at all, is based on review of the scatter found in the All Systems case and the fact that the scatter for the last-lot-average regression is greater.

The Optical Systems group results are shown in Table 15. Even with the adjustment, we were able to obtain results only for the size variables. The power equation statistics indicate little value in the

Table 15

OPTICAL SYSTEMS CASE REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Signif- icance	Sample Size
$4.52\ \text{Weight}^{.81}$	.63	.72	.01	9
$.69\ \text{Volume}^{.68}$	.71	.60	.01	7
$1.64\ \text{Power}^{.49}$	-.35	.95	-	4

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
AAA-4					-W
AAR-34					-W
AAS-35					-W
ALR-23	-W				
ASX-1	+W				
AVG-8			-W		
AVQ-9			+W		
AVQ-10		-W			
AWG-91R	+W				

NOTE: Regressions based on adjusted last-lot-average costs.

results, but the weight and volume equations offer some hope of utility. However, the standard errors shown are considered optimistic because of the adjustments discussed above.

Passive Electronic Countermeasures (ECM)

This group consists of equipment which detects and characterizes radar and ECM threats against aircraft. Excluded are ECM emitters (assigned to Active ECM) and infrared warning detectors (assigned to the Optical Systems group).

Table 16 displays our regression results for Passive ECM. Only five equations are shown; the sample for the power-technology case was too small to be useful. Of the five, only the weight and volume cases show any significance, but they have very large standard errors. The parameters of these two equations are reasonable, however, and they may have some value as rough estimators.

Table 16

PASSIVE ELECTRONIC COUNTERMEASURES CASE
REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Significance	Sample Size
$2.28\ \text{Weight}^{.74}$ (.05)	.67	.91	.05	6
$6.33\ \text{Weight}^{.71}\ e^{(-.08\text{SOLID} + .49\text{INTGRTD})}$ (-) (-) (-)	-.03	1.70	-	5
$1.02\ \text{Volume}^{.53}$ (.05)	.42	1.21	.10	6
$12.31\ \text{Volume}^{.19}\ e^{(1.00\text{SOLID} + 1.98\text{INTGRTD})}$ (-) (-) (-)	-.44	2.01	-	5
$57.98\ \text{Power}^{.21}$ (-)	-.28	1.99	-	5

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
ALR-15	+W				
ALR-41					-W
ALR-56			+W		
APR-25				-W	
APR-27					-W
APS-107D					-W

Power Management

This group consists of three "Integrated Electronic Central" systems, two of which had cost data, one of which was 100th unit cost. Needless to say, no regression analysis was possible. We retained these three systems as a separate group because it is reasonable to expect more centralization of power management functions in future aircraft.

Radars

This group contains radars variously designated as terrain-following, attack, and fire control, among others. Radars are characterized by the coordinated emission and reception of electromagnetic radiation, coupled with processing required to generate useful information.

A review of the data led us to exclude the F-111D's APQ-130 attack radar as an outlier. The acquisition history of this radar indicates atypical cost outcomes that are unlikely to be repeated in the future. Table 17 shows regression results for the remaining radars.

In the weight cases we see promising statistics, especially for the technology case. The weight exponent is nearly 1.0, all parameters are highly significant, and the average error is 25 percent. The volume-technology and both power cases show reasonbly good results as well.

Table 17

RADARS CASE REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Significance	Sample Size
$.15\ \text{Weight}^{1.26}$ (.01)	.79	.46	.01	15
$.41\ \text{Weight}^{1.02}\ e^{(.35\text{SOLID} + 1.31\text{INTGRTD})}$ (.01) (.05) (.01)	.94	.25	.01	11
$.02\ \text{Volume}$ (.01)	.35	.82	.05	14
$.004\ \text{Volume}^{1.03}\ e^{(1.26\text{SOLID} + 2.30\text{INTGRTD})}$ (.01) (.01) (.01)	.85	.41	.01	11
$.29\ \text{Power}^{.84}$ (.01)	.80	.46	.01	14
$.47\ \text{Power}^{.75}\ e^{(.44\text{SOLID} + .41\text{INTGRTD})}$ (.01) (.05) (-)	.82	.45	.01	11

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
APG-53	-W				
APG-63			+W		
APQ-72				-W	
APQ-88			-W		
APQ-92		-W			
APQ-99		-W			
APQ-113		+W			
APQ-114	-W				
APQ-116			-W		
APQ-120			-W		
APQ-128	+W				
APQ-130			+W[a]		
APQ-134	+W				
APQ-153	-W				
AWG-9RDR		+W			
AWG-10		-W			

[a]Not in sample.

Radar Navigation

This group consists of low-power radar equipment such as radar altimeters and doppler radars used for navigational purposes.

Table 18 shows three size-only equations; no meaningful results were available when technology variables were added. The volume equation shows the best statistics, but it indicates the presence of very large economies of scale. The weight equation exhibits a poorer fit to the data but it has more intuitive appeal. Little can be said for the power equation. Considering the small samples for this group and the extremely low density of the APN-122 (see Appendix B), we consider the weight equation to be the most reliable estimator.

Table 18

RADAR NAVIGATION CASE REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Signif-icance	Sample Size
$1.61\ \text{Weight}^{.92}$ (.05)	.54	.77	.05	7
$.68\ \text{Volume}^{.51}$ (.01)	.73	.55	.05	6
$3.08\ \text{Power}^{.52}$ (-)	-.18	1.30	-	5

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
APN-122			+W		
APN-141	-W				
APN-153					-W
APN-154V		-W			
APN-167			-W		
APN-185					-W
APN-194					-W

Radio Communication

This group assembles several similar types of equipment: identification-friend-or-foe (IFF) transponders, radio transceivers (all frequencies), intercoms, data links, etc. Still, because of the limited availability of 100th unit cost data, our largest sample contains only ten data points.

Table 19 lists the results for the three size-only cases. The technology cases suffered from the lack of integrated circuitry observations. None of the three size equations is significant, and the exponents shown have little appeal. The data offer no reasonable method to estimate Radio Communication system costs.

Table 19

RADIO COMMUNICATION CASE REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Significance	Sample Size
$5.46\ \text{Weight}^{.34}$ (-)	-.09	1.12	-	10
$21.72\ \text{Volume}^{-.08}$ (-)	-.15	.58	-	8
$22.24\ \text{Power}^{-.09}$ (-)	-.23	.71	-	6

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
AIC-14					-W
ARC-51					-W
ARC-51A					-W
ARC-109V	-W				
ARR-69	-W				
ARW-73					-W
ARW-77			-W		
ASW-25				-W	
MX-8811A	-W				
MX-9147/APX			+W		

Radio Navigation

This group includes LORAN, TACAN, direction finders, instrument landing systems, and similar equipment. All systems process radio information to produce navigation information.

Table 20 shows four equations, two of which (weight and volume) are significant. The weight equation is reasonable and its statistics are satisfactory, but its standard error is high. However, no useful alternative is presented in the results.

Table 20

RADIO NAVIGATION CASE REGRESSION RESULTS

I. EQUATIONS

Equation	Adjusted R^2	SEE	Significance	Sample Size
$.67\ \text{Weight}^{\underset{(.01)}{1.03}}$	.69	.64	.01	8
$.20\ \text{Weight}^{\underset{(-)}{1.17}}\ e^{\underset{(-)}{(1.14}\text{SOLID} + \underset{(-)}{1.78}\text{INTGRTD})}$	.53	.89	-	5
$.16\ \text{Volume}^{\underset{(.05)}{.75}}$	.40	.88	.10	7
$2.39\ \text{Power}^{\underset{(.10)}{.41}}$	.37	.68	-	6

II. RESIDUALS FOR WEIGHT-ONLY EQUATION

Equipment Designation	Residual Percentages 0 - 25	25 - 50	50 - 75	75 - 100	100+
ARA-63					-W
ARN-52					-W
ARN-84		+W			
ARN-86			-W		
ARN-92		+W			
ARN-112		+W			
OA-8639/ARA	-W				
OA-8697/ARD		-W			

DISCUSSION OF RESULTS

The statistical measures accompanying the cost estimating relationships developed for the twelve system-level cases provide one indication of their utility. Another evaluation of these CERs may be obtained by comparing them to a popular alternative avionics estimating technique: the use of average cost-per-pound factors. In essence, using the average cost per pound implies a linear relationship between cost and weight, with a slope equal to the average cost per pound and intercept at the origin. The accuracy of this estimator is indicated by its standard deviation (σ); assuming that cost-per-pound observations for a group are normally distributed, a one-σ band about the average theoretically contains 68 percent of the observations.

Cost-per-Pound Comparisons

Figure 6 is presented to display our comparison of regression results and cost-per-pound data for the twelve system-level cases. The rectangular gridlike figure for each case shows the average cost per pound and one-σ band (taken from Appendix B). The grid is divided into four columns on which bars are plotted showing the weight-only and three weight-and-technology results obtained previously. The endpoints of these bars were calculated by substituting the minimum and maximum weight values for the particular group without regard for technology level. In interpreting Fig. 6 we look at a bar or set of bars in relation to the one-σ cost-per-pound range and consider returns to scale and the ordering of technology levels. The following paragraphs address each set of results:

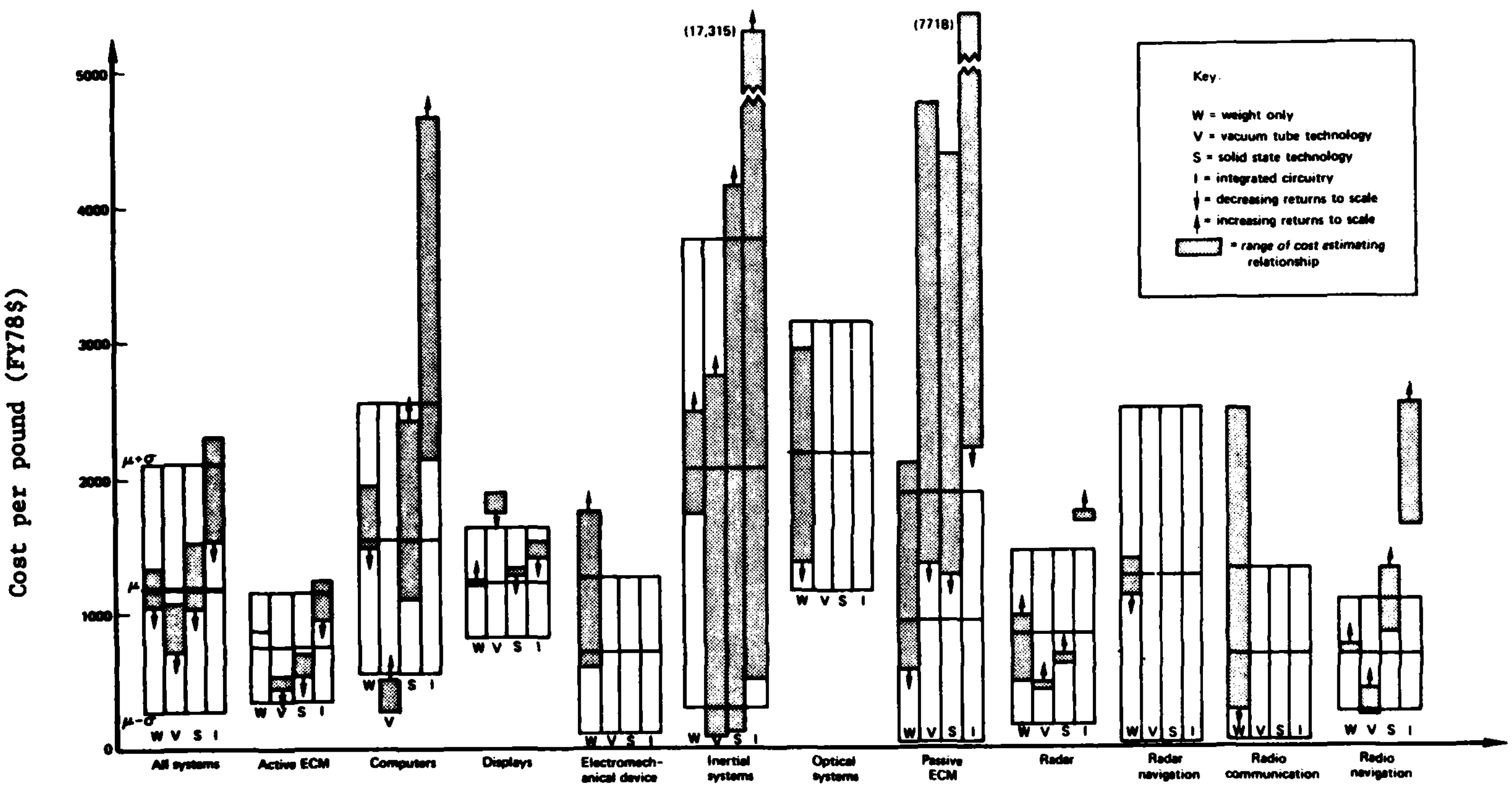

Fig. 6—Cost per pound versus regression results by group

All Systems. The CERs obtained for this case appear reasonable relative to the cost-per-pound data, and the set of technology equations does a good job of spanning the one-σ range. Decreasing returns to scale and appropriate ordering of the technologies are also positive aspects of the case. The upward bias of the technology equations reflects the positive skewing of the cost-per-pound distribution.

Active ECM. The technology equations for this case show the positive attributes mentioned above. The weight-only equation has an exponent of 1.0, leading to the single bar plot. It is not surprising that this value differs from the average cost per pound, since it is the quotient of mean cost and mean weight rather than the average of the individual observation quotients.

Computers. Here we see an adequate weight-only equation and wide-ranging technology equations reflecting increasing returns to scale. The range of the technology equations primarily results from using vacuum tube type weights with the integrated circuitry equation and vice versa. The increasing returns to scale were mentioned previously and are a cause for concern.

Displays. These results relate well to the cost-per-pound data but the inversion of the technology equations shows their weakness. The increasing returns of the weight-only case are slight and offer very little improvement over cost per pound only.

Electromechanical Devices. While the range shown here is appropriate, the direction is again counterintuitive. As previously mentioned, the power equation should be used in conjunction with the weight equation or cost-per-pound data.

Inertial Systems. While the statistical results for this group were adequate, the picture presented by Fig. 6 is not encouraging. The standard deviation in cost per pound is large for inertial systems, and the range of the technology equations is even larger. Despite increasing returns to scale, however, the weight-only equation appears to offer some advantages over the average cost per pound.

Optical Systems. The adjusted last lot data used for this case produced a weight-only equation that reasonably covers the range of cost per pound while reflecting decreasing returns to scale.

Passive ECM. The technology results here show the same flaws as the inertial systems case except for decreasing returns to scale. The weight-only equation produces reasonable results but is biased high relative to the cost-per-pound distribution.

Radars. The technology equations produce three very small bands, so that returns to scale are not significant. In essence, three cost-per-pound factors are estimated. The large value for integrated circuitry is not surprising in that the radars of this technology type are from the F-14A and F-15A. The weight-only case is less satisfactory because of the unexplained increasing returns to scale.

Radar Navigation. The weight-only equation here produces a reasonable if compact range of estimates and is probably an improvement on using a cost-per-pound factor.

Radio Communication. The weight-only estimator here shows decreasing returns to scale but excessive range and bias. It appears to be as unreliable as its statistics indicate.

Radio Navigation. The technology equations here span the cost-per-pound range with upward bias. The small range of the weight-only equation and its location offer little improvement over the cost-per-pound average but each serves to confirm the other.

Summary.

The regression results presented here offer mixed utility: Some are definite improvements over strict cost-per-pound estimating, while others introduce unwanted error. Increasing returns to scale present a puzzling problem in many cases; some statistically significant results are not supported by theoretical expectations. Positive aspects of the analysis are the general validity of the equipment groupings and the usefulness of the technology variables as estimating parameters. We suggest a broad approach for estimating at the systems level. This would involve using the CERs developed here, cost-per-pound data, and analogy to prior systems.

The numerous cases of increasing returns to scale warrant investigation beyond that possible in the study reported here. A basic assumption in cost estimating is that cost-per-pound decreases with increasing size (economy of scale in size). This is reasonable in most manufacturing cases and can be illustrated by comparing the resources consumed in lathe-finishing two rods of differing diameters. The capital cost and labor cost would be the same assuming constant spindle and feed speeds. Only the tool bit wear-rate would differ. Thus the cost-per-pound of finishing would be much less for the larger rod.

The regression results lead us to speculate whether the manufacture of avionics equipment is analogous. We suspect, for example, that larger and more complex avionics equipment may require relatively more assembly effort, thus generating overall diseconomies of scale. This is but one of many hypotheses which might be put forward in explanation of our statistical results. Research aimed at this diseconomies of scale question should be carried out, preferably in a manufacturing setting.

V. CONCLUSIONS AND RECOMMENDATIONS

In this section we consolidate our findings and attempt to put them in a policy context. Our comments address the structure of the analysis, regression analysis results, and the quality of the data.

STRUCTURE OF THE ANALYSIS

The analysis was structured by the scope of the data set, levels of analysis, and explanatory variables. The combined fighter-attack data set for combat aircraft showed no signs of being intractable. Expanding the data set to include other types of aircraft would be a debatable move. Equations using aircraft weight would not likely accept cargo aircraft. But other large aircraft, such as bombers and electronic special duty aircraft, may be analogous to the fighters and attack aircraft; their avionics complements are also aircraft-constrained. But to apply the combat aircraft data to any large aircraft, a linear fit of the suite data would be more realistic. Considering the three suite characteristics cases, the equipment mix becomes important when one attempts to estimate outside the fighter-attack domain.

Estimating relationships based on suites and systems seems to capture the essence of the available data most appropriately. There is no reasonable intermediate level of analysis that would be indicative of equipment function and componentry requirements. Analysis below the system level would require much greater depth of knowledge about equipment requirements and create an unmanageably large data base. This level of detail is better left for analysis at some point closer to the actual procurement.

The explanatory variables used in our analysis resulted from our own assessments and from interviews with knowledgeable personnel in the avionics field. Many variables were discarded at the start because they could not be reliably estimated themselves or were available too late in the development cycle. Many others could not be shown to be significant in our data, even though logic supported them. The problem comes from trying to overspecify the model to reflect the experience of particular programs. Parametric analysis serves to smooth the data and highlight the general trends, but individual cases reflect their own unique design and environment.

REGRESSION ANALYSIS RESULTS

Our results were mixed. The suites were accurately estimated with a time variable to capture change in technology, while the systems were poorly estimated with objective technology variables. At first glance, this outcome implies that aggregation dampens small differences among the data. However, further thought on the matter points to alternative explanations.

Technology and its proxy variable, time, appear to be at the root of these analytic difficulties, as has been previously stated. First flight date has been a good indicator of the technology available to the suite designer, while our three-tier technology categorization proved insufficient. More detailed measures of system component technology would probably help to explain the scatter in our sample, as would data on functions per unit size. Development of such measures and an additional data collection effort was not possible within the resources available for this research.

QUALITY OF THE DATA

It seems that no cost analysis research project is complete without the refrain, "if only we had more data." We, too, would have liked more cost data, but our more important message is a new verse bemoaning cost data without technical data.

The structure and implementation of the avionics recordkeeping system appears to be at fault here. The AN nomenclature system, which does not provide unique identifiers for similar but technically different pieces of equipment, is a particular problem. Contractor brochures on recent aircraft suites were our most informative sources, but they did little to correlate current system applications with prior ones.

Cost data by lot and pertinent technical information are important to any method of cost estimating. Considering the increasing importance of avionics equipment, a more concerted effort to collect and store both cost and technical/performance data systematically is very much in order.

Appendix A

SUITE LEVEL COST ESTIMATING DATA

This appendix presents data underlying Section III's analysis of suite level avionics costs. Table A-1 provides suite size parameters (i.e., weight, volume, density, and input power) and related costs for the 17 modern combat aircraft comprising the sample. The next table lists the aircraft characteristics used to explain costs. Similarly, Table A-3 gives the aircraft capabilities tested. Finally, Tables A-4 through A-20 supply information for the suites at the system level. The first portions of the tables indicate the systems' descriptions and prime and second-source manufactures (and divisions). The tables conclude with technical characteristics and functional group assignments. For reference, the tables are identified below:

Table	Title	
A-1	Avionics Suite Costs and Technical Data	
A-2	Suite Explanatory Variables--Aircraft Characteristics	
A-3	Suite Explanatory Variables--Aircraft Capabilities	
A-4	A-4M	Data at the System Level
A-5	A-6E	Data at the System Level
A-6	A-7D	Data at the System Level
A-7	A-7E	Data at the System Level
A-8	A-10A	Data at the System Level
A-9	F-4C	Data at the System Level
A-10	F-4D	Data at the System Level

A-11	F-4E	Data at the System Level
A-12	F-4J	Data at the System Level
A-13	F-5E	Data at the System Level
A-14	F-14A	Data at the System Level
A-15	F-15A	Data at the System Level
A-16	F-111A	Data at the System Level
A-17	F-111D	Data at the System Level
A-18	F-111E	Data at the System Level
A-19	F-111F	Data at the System Level
A-20	FB-111A	Data at the System Level

Table A-1

AVIONICS SUITE COSTS AND TECHNICAL DATA[a]

Aircraft	Estimated Total Cost	WEIGHT		VOLUME/DENSITY				POWER	
		Pounds	Cost	Pounds	$In.^3$	$Lb/In.^3$ [b]	Cost	VA[c]	Cost
A-4M	$ 480K	839.9	$ 462.5K	725.9	27554	.0263	$ 378.2K	6937	$ 332.7K
A-6E	1695	1735.1	1674.8	1144.8	34654	.0330	853.3	6368	679.9
A-7D	1000	1120.7	844.3	926.7	43298	.0214	696.4	10541	465.5
A-7E	1245	1439.9	1056.5	1181.9	51298	.0230	889.9	8300	538.9
A-10A	415	583.7	369.9	397.7	14586	.0260	288.4	3070	288.4
F-4C	930	1803.0	646.2	1570.0	48838	.0321	538.9	11991	524.8
F-4D	1190	1741.0	729.5	1570.0	51424	.0305	622.2	8237	393.9
F-4E	1059[d]	1247.0	721.8	1209.0	41314	.0293	690.7	5327	572.6
F-4J	1524[d]	2249.4	1523.8	2103.4	59929	.0351	1397.7	19369	1066.2
F-5E	135[d]	168.7	100.8	168.7	7673	.0220	100.8	1030	94.4
F-14A	3370	2198.8	2579.5	2080.8	64841	.0321	2519.4	29401	2050.2
F-15A	2750	1579.9	2488.0	1579.9	50820	.0311	2488.0	22497	2486.6
F-111A	1764[d]	1774.0	1669.1	1550.0	53547	.0289	1382.9	5621	732.9
F-111D	3705	2354.0	3563.6	1510.0	55503	.0272	1674.2	13529	1939.3
F-111E	2227[d]	2174.0	2112.3	1950.0	67371	.0289	1826.1	8926	755.4
F-111F	2230	2057.0	2148.0	1833.0	64676	.0283	1861.8	8926	722.5
FB-111A	2870	2503.0	2737.9	2219.0	81871	.0271	2252.9	7856	904.0

[a] All dollar values are FY78.

[b] Pounds numerator defined for systems with known value.

[c] Suite input power requirements in voltamperes.

[d] Complete.

Table A-2

SUITE EXPLANATORY VARIABLES--AIRCRAFT CHARACTERISTICS

Aircraft	Empty Weight (Klb)	Length (Ft)	Maximum Speed (Kn)	First Flight (Yr)	Number of Seats	Carrier Based
A-4M	10.8	40.3	568	1970	1	YES
A-6E	25.6	54.6	689	1970	2	YES
A-7D	19.8	46.1	606	1968	1	NO
A-7E	19.8	46.1	606	1968	1	YES
A-10A	19.9	53.3	410	1972	1	NO
F-4C	28.5	58.2	1222	1963	2	NO
F-4D	28.9	58.2	1222	1965	2	NO
F-4E	30.3	58.2	1222	1967	2	NO
F-4J	30.0	58.2	1222	1966	2	YES
F-5E	9.6	48.2	850	1972	1	NO
F-14A	38.9	61.9	1377	1970	2	YES
F-15A	25.8	55.6	1410	1972	1	NO
F-111A	46.2	73.5	1262	1964	2	NO
F-111D	46.6	73.5	1262	1968	2	NO
F-111E	46.2	73.5	1262	1969	2	NO
F-111F	47.5	73.5	1262	1971	2	NO
FB-111A	47.5	73.5	1262	1970	2	NO

Table A-3

SUITE EXPLANATORY VARIABLES--AIRCRAFT CAPABILITIES

Aircraft	Air-to-Air Capability	All-Weather Capability	Radar Missiles	Active ECM
A-4M	NO	YES	NO	YES
A-6E	NO	YES	NO	YES
A-7D	NO	YES	NO	YES
A-7E	NO	YES	NO	YES
A-10A	NO	NO	NO	NO
F-4C	YES	YES	YES	YES
F-4D	YES	YES	YES	YES
F-4E	YES	YES	YES	YES
F-4J	YES	YES	YES	YES
F-5E	YES	NO	NO	NO
F-14A	YES	YES	YES	YES
F-15A	YES	YES	YES	YES
F-111A	YES	YES	NO	YES
F-111D	YES	YES	NO	YES
F-111E	YES	YES	NO	YES
F-111F	YES	YES	NO	YES
FB-111A	NO	YES	NO	YES

Table A-4 (Page 1 of 2)

A-4M DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-100	ECM	Sanders Associates
AJB-7	Loft Bomb Computer	Lear Siegler Inc. (Instrument Div.)
ASN-41	Navigation Computer	Singer Co. (Gen. Perc. Inst.)
ALE-29	Chaff Dispenser	Tracor Inc.
AWE-1	Weapons Release	Bendix Corp. (Navigation and Control Div.)
AWW-4	Fuze Control	Unknown
ALR-45	Radar Homing/Warning	Itek Corp. (Applied Technology Div.)
ALR-50	Radar Warning Receiver	Magnavox Co.
APR-25	Radar Homing/Warning	Itek Corp. (Applies Technology Div.)
APR-27	Radar Receiver	Magnavox Co.
APN-141	Radar Electronic Altimeter	Bendix Corp. (Pacific Div.) Labs For Electronics
APN-153	Radar Doppler Navigation	Singer Co. (GPL Div.) Loral Electronics (Electronics Systems Div.)
APN-154V	Radar Beacon	Motorola Inc. (Military Electronics Div.) United Telecontrol
APN-194	Radar Electronic Altimeter	Honeywell Inc. (GAE Div.)
APG-53	Radar Fire Control	Stewart-Warner Corp. (Electronics Div.)
APX-72	IFF Transponder	Bendix Corp. (Radic Div.)
ARC-51	UHF Command Radio	Rockwell Int. (Collins Radio) Admiral Corp.
ARC-114	VHF/FM Radio	General Telephone Electr. Corp. (Sylvania Electronics Div.) E-Systems (Memcor Div.)
ARC-159	UHF Transceiver	Rockwell Int. (Collins Radio)
ARR-69	UHF Radio Receiver	RCA (Defense Communication Div.)
ARW-73	Radio Guidance	Martin-Marietta Corp.
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARA-63	Receiver Decoder	Cutler-Hammer (Airborne Inst. Lab.) Stewart-Warner Corp.
ARN-52,	TACAN Navigation	ITT Corp. (Federal Labs.) Republic Electronics
ARN-84	TACAN Navigation	Hoffman Electronics Corp. (Military Electronics Div.) ASC Systems Corp.

Table A-4 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-100	93.4	220.0	3974	.0554	3800	65	3	ACTIVE ECM
AJB-7	80.7	70.0	2102	.0333	407	64	1	COMPUTER
ASN-41	95.7	32.0					2	COMPUTER
ALE-29	79.2	43.0	1398	.0308	28		2	ELECTROMECHANICAL
AWE-1	105.8	9.0	408	.0221	5	66	1	ELECTROMECHANICAL
AWW-4	AVG							ELECTROMECHANICAL
ALR-45	AVG	46.0				72		PASSIVE ECM
ALR-50	AVG	16.0				72		PASSIVE ECM
APR-25	87.2	37.0	538	.0241	74	66	2	PASSIVE ECM
APR-27	86.6	11.0	760	.0145	420	66	1	PASSIVE ECM
APN-141	83.5	11.4	156	.0731		64	2	RADAR NAVIGATION
APN-153	74.3	53.0	3629	.0146	425	63	2	RADAR NAVIGATION
APN-154V	85.7	6.0	190	.0316		66	2	RADAR NAVIGATION
APN-194	98.1	7.0			400	70		RADAR NAVIGATION
APG-53	71.6	90.0	6394	.0141	400	57	1	RADAR
APX-72	AVG	16.5	479	.0344				RADIO COMM
ARC-51	85.5	33.0	1296	.0256	180	63	2	RADIO COMM
ARC-114	NONE							RADIO COMM
ARC-159	AVG	9.0	173	.0520		74	3	RADIO COMM
ARR-69	78.5	10.0	318	.0315		65	2	RADIO COMM
ARW-73	109.8	20.0	1322	.0151	170	60		RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARA-63	100.0	13.0				72	2	RADIO NAVIGATION
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-84	98.1	29.0	766	.0379	163	71	3	RADIO NAVIGATION

Table A-5 (Page 1 of 2)

A-6E DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-100	ECM	Sanders Associates
ASQ-133	Ballistic Computer	IBM Corp. (Federal Systems Div.)
ASQ-155	Ballistic Computer	IBM Corp./Fairchild Industries
CP-1005A	Air Data Computer	Conrac
AVA-1	Vertical Display Indicator	Kaiser Industries Corp.
ALE-29	Chaff Dispenser	Tracor Inc.
ALE-32	Chaff Dispenser	Lundy Electronics
AWW-4	Fuze Control	Unknown
ASN-31	Intertial Navigation	Litton Industries (Guidance and Control Div.)
ASN-92	Inertial Navigation	Litton Industries (Guidance and Control Div.)
ALR-45	Radar Homing/Warning	Itek Corp. (Applied Technology Div.)
ALR-50	Radar Warning Receiver	Magnavox Co.
APR-25	Radar Homing/Warning	Itek Corp. (Applies Techaclogy Div.)
APR-27	Radar Receiver	Magnavox Co.
ASQ-57	Integrated Electr. Central	Rockwell Int. (Collins Radio)
APN-153	Radar Doppler Navigation	Singer Co. (GFL Div.) Loral Electronics (Electronics Systems Div.)
APN-154V	Radar Beacon	Motorola Inc. (Military Electronics Div.) United Telecontrol
APN-194	Radar Electronic Altimeter	Honeywell Inc. (GAF Div.)
APQ-148	Radar Attack	United Technologies (Norden)
AIC-14	Intercom	West Electronics Monmouth Electric Co.
APX-72	IFF Transponder	Bendix Corp. (Radio Div.)
ARC-57	UHF Command Radio	General Dynamics Corp.
ARC-159	UHF Transceiver	Rockwell Int. (Collins Radio)
ARN-67	Radio Guidance	Esterline Corp. (Babcock Electr.)
ARN-73	Radio Guidance	Martin-Marietta Corp.
ASW-25	UHF Digital Data Comm.	Radiation Systems
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARN-84	TACAN Navigation	Hoffman Electronics Corp. (Military Electronics Div.) ASC Systems Corp.
CV-3194	Data Converter	Litton Industries

Table A-5 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-100	93.4	220.0	3974	.0554	3800	65	3	ACTIVE ECM
ASQ-133	86.0	176.0	1537	.1145	260	70	2	COMPUTER
ASQ-155	94.5	69.0	4666	.0148	160	70	2	COMPUTER
CP-1005A	94.9	50.4	1037	.0486	70	70	2	COMPUTER
AVA-1	103.6	27.0	1106	.0244		70		DISPLAY
ALE-29	79.2	43.0	1398	.0308	28		2	ELECTROMECHANICAL
ALE-32	AVG							ELECTROMECHANICAL
AWW-4	AVG							ELECTROMECHANICAL
ASN-31	80.0	130.0				60	1	INERTIAL
ASN-92	AVG	123.9	4493	.0276				INERTIAL
ALR-45	AVG	46.0				72		PASSIVE ECM
ALR-50	AVG	16.0				72		PASSIVE ECM
APR-25	87.2	37.0	1538	.0241	74	66	2	PASSIVE ECM
APR-27	86.6	11.0	760	.0145	420	66	1	PASSIVE ECM
ASQ-57	AVG							POWER MANAGEMENT
APN-153	74.3	53.0	3629	.0146	425	63	2	RADAR NAVIGATION
APN-154V	85.7	6.0	190	.0316		66	2	RADAR NAVIGATION
APN-194	98.1	7.0			400	70		RADAR NAVIGATION
APQ-148	AVG	365.0						RADAR
AIC-14	80.2	12.3						RADIO COMM
APX-72	AVG	16.5	479	.0344				RADIO COMM
ARC-57	NONE							RADIO COMM
ARC-159	AVG	9.0	173	.0520		74	3	RADIO COMM
ARW-67	AVG	11.0	500	.0220	46	60	2	RADIO COMM
ARW-73	109.8	20.0	1322	.0151	170	60		RADIO COMM
ASW-25	79.0	14.0						RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARN-84	98.1	29.0	766	.0379	163	71	3	RADIO NAVIGATION
CV-3194	103.7	29.0	1210	.0240	100	72	2	MISCELLANEOUS

Table A-6 (Page 1 of 2)

A-7D DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-87	ECM Pod Equipment	General Electric
ALQ-100	ECM	Sanders Associates
ASN-91	TAC Computer	IBM Corp. (Federal Systems Div.)
CPU-80A	Flight Direction Computer	Unknown
AQU-6	Horizontal Situation Ind.	Unknown
ASN-99	Projected Map Display	Control Data Corp.
		(Computing Devices of Canada)
AVQ-7	Head-Up Display	EA Industrial Corp./Elliot Bros.
AWW-2	Bomb Fuse Control	Polyphase Instruments
ASN-90	Inertial Measurement	Singer Co. (Kearfott Div.)
ALR-50	Radar Warning Receiver	Magnavox Co.
APR-36	Radar Warning Receiver	Itek Corp.
APR-37	Radar Warning Receiver	Itek Corp.
APN-141	Radar Electronic Altimeter	Bendix Corp. (Pacific Div.)
		Labs For Electronics
APN-154V	Radar Beacon	Motorola Inc.
		(Military Electronics Div.)
		United Telecontrol
APN-190	Radar Doppler	Singer Co. (Kearfott Div.)
APQ-126	Radar Terrain Avoid/Map	Texas Instruments Inc.
APX-72	IFF Transponder	Bendix Corp. (Radio Div.)
ARC-51	UHF Command Radio	Rockwell Int. (Collins Radio)
		Admiral Corp.
ARW-77	Radio Guidance	Martin-Marietta Corp.
		(Orlando Div.)
ASW-25	UHF Digital Data Comm.	Radiation Systems
FM-622A	VHF/FM Radio	Magnavox Co.
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.)
		Republic Electronics
ARN-92	LORAN C/D Navigation	ITT Corp. (Federal Labs.)

Table A-6 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-87	AVG				3500			ACTIVE ECM
ALQ-100	93.4	220.0	3974	.0554	3800	65	3	ACTIVE ECM
ASN-91	89.0	80.0	2592	.0309	325	67	2	COMPUTER
CPU-80A	AVG							COMPUTER
AQU-6	AVG							DISPLAY
ASN-99	101.9	42.0				68	2	DISPLAY
AVQ-7	AVG	84.0				67		DISPLAY
AWW-2	AVG							ELECTROMECHANICAL
ASN-90	87.7	70.0	1728	.0405		67	2	INERTIAL
ALR-50	AVG	16.0				72		PASSIVE ECM
APR-36	AVG	38.0				67		PASSIVE ECM
APR-37	AVG					67		PASSIVE ECM
APN-141	83.5	11.4	156	.0731		64	2	RADAR NAVIGATION
APN-154V	85.7	6.0	190	.0316		66	2	RADAR NAVIGATION
APN-190	AVG	65.0	5478	.0119		67	2	RADAR NAVIGATION
APQ-126	AVG	230.0	20736	.0111	2200	67	2	RADAR
APX-72	AVG	16.5	479	.0344				RADIO COMM
ARC-51	85.5	33.0	1296	.0256	80	63	2	RADIO COMM
ARW-77	96.4	25.0	624	.0401		64	2	RADIO COMM
ASW-25	79.0	14.0						RADIO COMM
FM-622A	AVG	27.3	604	.0452	116			RADIO COMM
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-92	90.0	91.5	3136	.0292		67	2	RADIO NAVIGATION

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AN ANALYSIS OF COMBAT AIRCRAFT AVIONICS PRODUCTION COSTS.(U)
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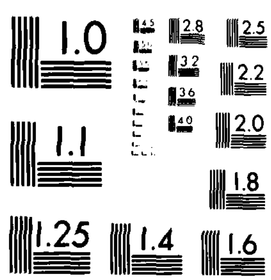

Table A-7 (Page 1 of 2)

A-7E DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-100	ECM	Sanders Associates
ALQ-120	ECM	Sanders Associates
ALQ-126	ECM	Sanders Associates
AJB-3A	Loft Bomb Computer	Texas Instruments Inc. (Apparatus Div.) Lear Seigler Inc. (Instrument Div.)
ASN-91	TAC Computer	IBM Corp. (Federal Systems Div.)
ASN-99	Projected Map Display	Control Data Corp. (Computing Devices of Canada)
AVQ-7	Head-Up Display	EA Industrial Corp./Elliot Bros.
ALE-29	Chaff Dispenser	Tracor Inc.
ALE-39	Chaff Dispenser	Goodyear Aerospace
AWW-2	Bomb Fuse Control	Polyphase Instruments
AWW-4	Fuze Control	Unknown
ASN-90	Inertial Measurement	Singer Co. (Kearfott Div.)
ALR-45	Radar Homing/Warning	Itek Corp. (Applied Technology Div.)
ALR-50	Radar Warning Receiver	Magnavox Co.
APR-25	Radar Homing/Warning	Itek Corp. (Applies Technology Div.)
APR-27	Radar Receiver	Magnavox Co.
APN-141	Radar Electronic Altimeter	Bendix Corp. (Pacific Div.) Labs For Electronics
APN-190	Radar Doppler	Singer Co. (Kearfott Div.)
APN-194	Radar Electronic Altimeter	Honeywell Inc. (GAE Div.)
APQ-126	Radar Terrain Avoid/Map	Texas Instruments Inc.
AIC-25	Intercom	Andrea Radio Corp. Nelcor Electronics Corp. Monmouth Electric Co.
APX-72	IFF Transponder	Bendix Corp. (Radio Div.)
ARC-51	UHF Command Radio	Rockwell Int. (Collins Radio) Admiral Corp.
ARR-69	UHF Radio Receiver	RCA (Defense Communication Div.)
ASW-25	UHF Digital Data Comm.	Radiation Systems
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARA-63	Receiver Decoder	Cutler-Hammer (Airborne Inst. Lab.) Stewart-Warner Corp.
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.) Republic Electronics
ARN-84	TACAN Navigation	Hoffman Electronics Corp. (Military Electronics Div.) ASC Systems Corp.

Table A-7 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	LVL	FUNCTIONAL GROUP
ALQ-100	93.4	220.0	3974	.0554	3800	65	3	ACTIVE ECM
ALQ-120	NONE							ACTIVE ECM
ALQ-126	93.4	185.0	3974	.0466		72	3	ACTIVE ECM
AJB-3A	83.4	83.0	3454	.0240	245	64	1	COMPUTER
ASN-91	89.0	80.0	2592	.0309	325	67	2	COMPUTER
ASN-99	101.9	42.0				68	2	DISPLAY
AVQ-7	AVG	84.0				67		DISPLAY
ALE-29	79.2	43.0	1398	.0308	28		2	ELECTROMECHANICAL
ALE-39	AVG	36.0						ELECTROMECHANICAL
AWW-2	AVG							ELECTROMECHANICAL
AWW-4	AVG							ELECTROMECHANICAL
ASN-90	87.7	70.0	1728	.0405		67	2	INERTIAL
ALR-45	AVG	46.0				72		PASSIVE ECM
ALR-50	AVG	16.0				72		PASSIVE ECM
APR-25	87.2	37.0	1538	.0241	74	66	2	PASSIVE ECM
APR-27	86.6	11.0	760	.0145	420	66	1	PASSIVE ECM
APN-141	83.5	11.4	156	.0731		64	2	RADAR NAVIGATION
APN-190	AVG	65.0	5478	.0119		67	2	RADAR NAVIGATION
APN-194	98.1	7.0			400	70		RADAR NAVIGATION
APQ-126	AVG	230.0	20736	.0111	2200	67	2	RADAR
AIC-25	NONE							RADIO COMM
APX-72	AVG	16.5	479	.0344				RADIO COMM
ARC-51	85.5	33.0	1296	.0256	180	63	2	RADIO COMM
ARR-69	78.5	10.0	318	.0315		65	2	RADIO COMM
ASW-25	79.0	14.0						RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARA-63	100.0	13.0				72	2	RADIO NAVIGATION
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-84	98.1	29.0	766	.0379	163	71	3	RADIO NAVIGATION

Table A-8 (Page 1 of 2)

A-10A DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
CSV-80	Flight Direction Computer	Unknown
Head-Up Dspl	Head-Up Display (A-10)	McDonnell Douglas Corp. Kaiser Industries
TV Monitor	TV Monitor (A-10)	Cardion Electronics
ALE-40(V)	Chaff Dispenser	Tracor Inc.
Arm.Cont.Sys.	Armament Cont. Sys. (A-10)	Fairchild Industries
LSI6000A	Attitude Reference	Lear Siegler Inc.
AAS-35	Laser Search Tracker	Martin Marietta Corp.
ALR-69V	Radar Warning Receiver	Itek Corp.
AIC-18	Intercom	Andrea Radio Corp.
APX-101	IFF Transponder	Teledyne
ARC-164	UHF/AM Radio	Magnavox Co.
FM-622A	VHF/FM Radio	Magnavox Co.
UPN-25	X-Band Beacon	Motorola Inc.
Wilcox 807	VHF/AM Radio	Wilcox Electric Co.
ARN-108	Instrument Landing Sys.	Rockwell Int. (Collins Radio)
ARN-118	TACAN	Rockwell Int. (Collins Radio)
OA-8697/ARD	UHF/ADF	Rockwell Int. (Collins Radio)

Table A-8 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
CSV-80	AVG	6.8	204	.0333	42			COMPUTER
Head-UP DSPL	111.5	65.2	4755	.0137	365			DISPLAY
TV Monitor	84.0	17.0	431	.0394	155			DISPLAY
ALE-40(V)	AVG	186.0						ELECTROMECHANICAL
Arm.Cont.Sys.	93.6							ELECTROMECHANICAL
LSI6000A	113.2	27.0	761	.0355	84			INERTIAL
AAS-35	AVG	56.2	2531	.0222	523			OPTICAL
ALR-69V	AVG	98.5	1690	.0583	885			PASSIVE ECM
AIC-18	AVG	5.2	207	.0251	22			RADIO COMM
APX-101	AVG	14.7	380	.0387	65		2	RADIO COMM
ARC-164	AVG	17.0	173	.0984	110			RADIO COMM
FM-622A	AVG	27.3	604	.0452	116			RADIO COMM
UPN-25	AVG	3.3	39	.0846	350			RADIO COMM
Wilcox 807	NONE	18.0	646	.0279	302			RADIO COMM
ARN-108	AVG	8.0	216	.0370	45			RADIO NAVIGATION
ARN-118	AVG	44.0	2108	.0209	280			RADIO NAVIGATION
OA-8697/ARD	97.9	7.5	487	.0154	28			RADIO NAVIGATION

Table A-9 (Page 1 of 2)

F-4C DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-75	ECM	General Electric (Light Military Electronics Dept.)
ALQ-100	ECM	Sanders Associates
AJB-7	Loft Bomb Computer	Lear Siegler Inc. (Instrument Div.)
APA-157	Fire Control Group	Raytheon
ASN-46A	Navigation Computer	Bendix Corp. (Navigation and Control Div.)
ASN-48	Inertial Navigation	Litton Industries (Guidance and Control Div.)
ALR-31	ECM Receiver	Loral Electronics
APR-25	Radar Homing/Warning	Itek Corp. (Applied Technology Div.)
ASQ-19B	Integrated Electr. Central	Rockwell Int. (Collins Radio)
APN-155	Radar Altimeter	RCA (Defense Electronics Prod. Div.) Stewart-Warner Corp. (Electronics Div.)
APQ-100	Radar Control/Intercept	Westinghouse Electric Corp. (Aerospace Div.)
APX-76A	IFF Interrogator	Hazeltine Corp. (Electronic Div.)
ARC-105	VHF Radio Communication	Rockwell Int. (Collins Radio)
ARW-77	Radio Guidance	Martin-Marietta Corp. (Orlando Div.)
ARN-83	VHF Direction Finder	Rockwell Int. (Collins Radio)

Table A-9 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-75	NONE				11300			ACTIVE ECM
ALQ-100	93.4	220.0	3974	.0554	3800	65	3	ACTIVE ECM
AJB-7	80.7	70.0	2102	.0333	407	64	1	COMPUTER
APA-157	61.5	233.0			3000		1	COMPUTER
ASN-46A	AVG	31.0	831	.0373	85	65	2	COMPUTER
ASN-48	94.6	95.0	4147	.0229		60	1	INERTIAL
ALR-31	NONE							PASSIVE ECM
APR-25	87.2	37.0	1538	.0241	74	66	2	PASSIVE ECM
ASQ-19B	AVG	198.0	7594	.0261	775	69	1	POWER MANAGEMENT
APN-155	AVG	19.0	691	.0275	80	69	2	RADAR NAVIGATION
APQ-100	AVG	856.0	26611	.0322	3600	62	1	RADAR
APX-76A	AVG	19.0	726	.0262	170		1	RADIO COMM
ARC-105	AVG							RADIO COMM
ARW-77	96.4	25.0	624	.0401		64	2	RADIO COMM
ARN-83	AVG							RADIO NAVIGATION

Table A-10 (Page 1 of 2)

F-4D DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-71	ECM	Hughes Aircraft
AJB-7	Loft Bomb Computer	Lear Siegler Inc. (Instrument Div.)
APA-157	Fire Control Group	Raytheon
ASN-46A	Navigation Computer	Bendix Corp. (Navigation and Control Div.)
ASQ-91	Bomb Computer	Litton Industries
ASN-63	Inertial Navigation	Litton Industries (Guidance and Control Div.)
ASG-22	Optical Sight Lead Comp.	General Electric (Light Military Electronic Dept.)
AVQ-9	Laser Designator	Martin-Marietta Corp.
ALT-34	ECM	Borders Electronics General Electric
APR-38	Radar Homing/Warning	IBM Corp. (Federal Systems Div.)
APS-107D	Radar Homing/Warning	Bendix Corp. (Electrodynamics Div.)
ASQ-19B	Integrated Electr. Central	Rockwell Int. (Collins Radio)
APN-155	Radar Altimeter	RCA (Defense Electronics Prod. Div.) Stewart-Warner Corp. (Electronics Div.)
APQ-109	Radar Control/Intercept	Westinghouse Electric Corp.
APX-76A	IFF Interrogator	Hazeltine Corp. (Electronic Div.)
ARC-105	VHF Radio Communication	Rockwell Int. (Collins Radio)
ARW-77	Radio Guidance	Martin-Marietta Corp. (Orlando Div.)
ARN-83	VHF Direction Finder	Rockwell Int. (Collins Radio)
ARN-92	LORAN C/D Navigation	ITT Corp. (Federal Labs.)

Table A-10 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-71	NONE				3500			ACTIVE ECM
AJB-7	80.7	70.0	2102	.0333	407	64	1	COMPUTER
APA-157	61.5	233.0			3000		1	COMPUTER
ASN-46A	AVG	31.0	831	.0373	85	65	2	COMPUTER
ASQ-91	107.5	41.0	1409	.0291	120	69	2	COMPUTER
ASN-63	96.3	95.0	4147	.0229		66		INERTIAL
ASG-22	AVG							OPTICAL
AVQ-9	AVG	10.0	858	.0117				OPTICAL
ALT-34	NONE				840			PASSIVE ECM
APR-38	AVG					74	3	PASSIVE ECM
APS-107D	96.8	42.5	2004	.0212		70	3	PASSIVE ECM
ASQ-19B	AVG	198.0	7594	.0261	775	69	1	POWER MANAGEMENT
APN-155	AVG	19.0	691	.0275	80	69	2	RADAR NAVIGATION
APQ-109	AVG	866.0	27302	.0317	3600	64	1	RADAR
APX-76A	AVG	19.0	726	.0262	170		1	RADIO COMM
ARC-105	AVG							RADIO COMM
ARW-77	96.4	25.0	624	.0401		64	2	RADIO COMM
ARN-83	AVG							RADIO NAVIGATION
ARN-92	90.0	91.5	3136	.0292		67	2	RADIO NAVIGATION

Table A-11 (Page 1 of 2)

F-4E DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-119	ECM System	Westinghouse Electric Corp. (Defense and Space Center)
AJB-7	Loft Bomb Computer	Lear Siegler Inc. (Instrument Div.)
ASN-46A	Navigation Computer	Bendix Corp. (Navigation and Control Div.)
ASQ-91	Bomb Computer	Litton Industries
ASN-63	Inertial Navigation	Litton Industries (Guidance and Control Div.)
ASG-26	Optical Sight Lead Comp.	General Electric (Light Military Electronic Dept.)
AVQ-23	Designator	Westinghouse Electric Corp. (Aerospace Div.)
APR-36	Radar Warning Receiver	Itek Corp.
APR-37	Radar Warning Receiver	Itek Corp.
ASQ-19B	Integrated Electr. Central	Rockwell Int. (Collins Radio)
APN-155	Radar Altimeter	RCA (Defense Electronics Prod. Div.) Stewart-Warner Corp. (Electronics Div.)
APQ-120	Radar Forward Looking	Westinghouse Electric Corp. (Aerospace Div.)
APX-76A	IFF Interrogator	Hazeltine Corp. (Electronic Div.)
ARC-105	VHF Radio Communication	Rockwell Int. (Collins Radio)
ARW-77	Radio Guidance	Martin-Marietta Corp. (Orlando Div.)
ARN-93	VHF Direction Finder	Rockwell Int. (Collins Radio)
ARN-101	LORAN	Lear Siegler Inc. (Instrument Div.)

Table A-11 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-119	AVG							ACTIVE ECM
AJB-7	80.7	70.0	2102	.0333	407	64	1	COMPUTER
ASN-46A	AVG	31.0	831	.0373	85	65	2	COMPUTER
ASQ-91	107.5	41.0	1409	.0291	120	69	2	COMPUTER
ASN-63	96.3	95.0	4147	.0229		66		INERTIAL
ASG-26	AVG							OPTICAL
AVQ-23	AVG							OPTICAL
APR-36	AVG	38.0				67		PASSIVE ECM
APR-37	AVG					67		PASSIVE ECM
ASQ-19B	AVG	198.0	7594	.0261	775	69	1	POWER MANAGEMENT
APN-155	AVG	19.0	691	.0275	80	69	2	RADAR NAVIGATION
APQ-120	88.3	667.0	21082	.0316	3410	67	2	RADAR
APX-76A	AVG	19.0	726	.0262	170		1	RADIO COMM
ARC-105	AVG							RADIO COMM
ARW-77	96.4	25.0	624	.0401		64	2	RADIO COMM
ARN-83	AVG							RADIO NAVIGATION
ARN-101	AVG	44.0	2108	.0209	280			RADIO NAVIGATION

Table A-12 (Page 1 of 2)

F-4J DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-91	ECM	Magnavox Co.
ALQ-100	ECM	Sanders Associates
ALQ-126	ECM	Sanders Associates
AJB-7	Loft Bomb Computer	Lear Siegler Inc. (Instrument Div.)
ASN-39	Navigation Computer	Bendix Corp.
ALE-29	Chaff Dispenser	Tracor Inc.
AWW-1	Fuse Function Control	Rauland Borg Co.
AVG-8	Target Acquisition	Honeywell Inc.
ALR-45	Radar Homing/Warning	Itek Corp. (Applied Technology Div.)
ALR-50	Radar Warning Receiver	Magnavox Co.
APR-25	Radar Homing/Warning	Itek Corp. (Applied Technology Div.)
APR-27	Radar Receiver	Magnavox Co.
ASQ-19B	Integrated Electr. Central	Rockwell Int. (Collins Radio)
APN-141	Radar Electronic Altimeter	Bendix Corp. (Pacific Div.) Labs For Electronics
APN-154V	Radar Beacon	Motorola Inc. (Military Electronics Div.) United Telecontrol
APN-194	Radar Electronic Altimeter	Honeywell Inc. (G&F Div.)
AWG-10	Msl Fire Control System	Westinghouse Electric Corp. (Aerospace Div.)
APX-76A	IFF Interrogator	Hazeltine Corp. (Electronic Div.)
ARR-69	UHF Radio Receiver	RCA (Defense Communication Div.)
ASW-25	UHF Digital Data Comm.	Radiation Systems
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARA-63	Receiver Decoder	Cutler-Hammer (Airborne Inst. Lab.) Stewart-Warner Corp.
ARN-86	TACAN Navigation	Stewart-Warner Corp.

Table A-12 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-91	AVG	50.0	1296	.0386		67	3	ACTIVE ECM
ALQ-100	93.4	220.0	3974	.0554	3800	65	3	ACTIVE ECM
ALQ-126	93.4	185.0	3974	.0466		72	3	ACTIVE ECM
AJB-7	80.7	70.0	2102	.0333	407	64	1	COMPUTER
ASN-39	77.9	25.0				61	2	COMPUTER
ALE-29	79.2	43.0	1398	.0308	28		2	ELECTROMECHANICAL
AWW-1	AVG	17.0	824	.0206			1	ELECTROMECHANICAL
AVG-8	98.9	25.0				71		OPTICAL
ALR-45	AVG	46.0				72		PASSIVE ECM
ALR-50	AVG	16.0				72		PASSIVE ECM
APR-25	87.2	37.0	1538	.0241	74	66	2	PASSIVE ECM
APR-27	86.6	11.0	760	.0145	420	66	1	PASSIVE ECM
ASQ-19B	AVG	198.0	7594	.0261	775	69	1	POWER MANAGEMENT
APN-141	83.5	11.4	156	.0731		64	2	RADAR NAVIGATION
APN-154V	85.7	6.0	190	.0316		66	2	RADAR NAVIGATION
APN-194	98.1	7.0			400	70		RADAR NAVIGATION
AWG-10	85.1	1180.0	33696	.0350	13000	64	2	RADAR
APX-76A	AVG	19.0	726	.0262	170		1	RADIO COMM
ARR-69	78.5	10.0	318	.0315		65	2	RADIO COMM
ASW-25	79.0	14.0						RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARA-63	100.0	13.0				72	2	RADIO NAVIGATION
ARN-86	95.7	39.0	1037	.0376	250			RADIO NAVIGATION

Table A-13 (Page 1 of 2)

F-5E DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ASG-29	Optical Sight Lead Comp.	General Electric
APQ-153	Radar Fire Control	Emerson Electric
AIC-18	Intercom	Andrea Radio Corp.
APX-72	IFF Transponder	Bendix Corp. (Radio Div.)
ARC-150	UHF Radio	Magnavox Co.
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARN-65	TACAN Navigation	Hoffman Electronics Corp. (Military Electronics Div.)
ARN-84	TACAN Navigation	Hoffman Electronics Corp. (Military Electronics Div.) ASC Systems Corp.

Table A-13 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ASG-29	AVG							OPTICAL
APQ-153	89.2	111.0	5875	.0189	800	71	2	RADAR
AIC-18	AVG	5.2	207	.0251	22			RADIO COMM
APX-72	AVG	16.5	479	.0344				RADIO COMM
ARC-150	AVG							RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARN-65	AVG							RADIO NAVIGATION
ARN-84	98.1	29.0	766	.0379	163	71	3	RADIO NAVIGATION

Table A-14 (Page 1 of 2)

F-14A DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-100	ECM	Sanders Associates
ALQ-126	ECM	Sanders Associates
ALQ-128	ECM Mulitmode	Magnavox Co.
AWG-9COMP.	Computer	Hughes Aircraft
CP-1035A	Air Data Computer	Garrett Airesearch Co.
ASA-79	Multi Mode Display	IBM Corp.
AVA-12	Vertical/Head-Up Display	Kaiser Industries Corp.
AWG-9DISP.	Displays	Hughes Aircraft
ALE-29	Chaff Dispenser	Tracor Inc.
ALE-39	Chaff Dispenser	Goodyear Aerospace
AWG-9MSLAUX	Missile Aux.	Hughes Aircraft
AWG-15	Fire Control System	Fairchild Industries
AWW-5	Fuse Control	General Dynamics Corp.
ASN-92	Inertial Navigation	Litton Industries
		(Guidance and Control Div.)
ALR-23	ECM IR Receiver	AVCO Corp.
AWG-9IR	Infrared Sensor	Hughes Aircraft
ALR-25	ECM	Sanders Associates
		Ling-Temco-Vought Inc./Raytheon
ALR-45	Radar Homing/Warning	Itek Corp.
		(Applied Technology Div.)
ALR-50	Radar Warning Receiver	Magnavox Co.
APR-25	Radar Homing/Warning	Itek Corp.
		(Applies Technology Div.)
APR-27	Radar Receiver	Magnavox Co.
ASQ-85	Integrated Electr. Central	RCA
APN-154V	Radar Beacon	Motorola Inc.
		(Military Electronics Div.)
		United Telecontrol
APN-194	Radar Electronic Altimeter	Honeywell Inc. (GAE Div.)
AWG-9RDR	Radar	Hughes Aircraft
APX-72	IFF Transponder	Bendix Corp. (Radio Div.)
APX-76A	IFF Interrogator	Hazeltine Corp. (Electronic Div.)
ARC-51A	UHF Command Radio	Rockwell Int. (Collins Radio)
		Admiral Corp.
ARC-159	UHF Transceiver	Rockwell Int. (Collins Radio)
ARR-69	UHF Radio Receiver	RCA (Defense Communication Div.)
ASW-27	Data Link	Litton Industries
		(Data Systems Div.)
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARA-63	Receiver Decoder	Cutler-Hammer (Airborne Inst. Lab.)
		Stewart-Warner Corp.
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.)
		Republic Electronics
ARN-84	TACAN Navigation	Hoffman Electronics Corp.
		(Military Electronics Div.)
		ASC Systems Corp.

Table A-14 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-100	93.4	220.0	3974	.0554	3800	65	3	ACTIVE ECM
ALQ-126	93.4	185.0	3974	.0466		72	3	ACTIVE ECM
ALQ-128	96.3	58.6	2765	.0212	168	76	3	ACTIVE ECM
AWG-9COMP	85.6	175.0	5108	.0343	1000	70	2	COMPUTER
CP-1035A	97.2	33.2	691	.0481	206	70	2	COMPUTER
ASA-79	88.9	62.9	3231	.0195	505	70	2	DISPLAY
AVA-12	85.5	121.0	5357	.0226	810	70	1	DISPLAY
AWG-9DISP	AVG							DISPLAY
ALE-29	79.2	43.0	1398	.0308	28		2	ELECTROMECHANICAL
ALE-39	AVG	36.0						ELECTROMECHANICAL
AWG-9MsI Aux.	AVG							ELECTROMECHANICAL
AWG-15	88.0	46.7	2347	.0199	102	70	2	ELECTROMECHANICAL
AWW-5	NONE							ELECTROMECHANICAL
ASN-92	AVG	123.9	4493	.0276				INERTIAL
ALR-23	AVG	63.0	1693	.0372	910	67		OPTICAL
AWG-9IR	AVG	66.0	1901	.0347				OPTICAL
ALR-25	NONE							PASSIVE ECM
ALR-45	AVG	46.0				72		PASSIVE ECM
ALR-50	AVG	16.0				72		PASSIVE ECM
APR-25	87.2	37.0	1538	.0241	74	66	2	PASSIVE ECM
APR-27	86.6	11.0	760	.0145	420	66	1	PASSIVE ECM
ASQ-85	NONE							POWER MANAGEMENT
APN-154V	85.7	6.0	190	.0316		66	2	RADAR NAVIGATION
APN-194	98.1	7.0			400	70		RADAR NAVIGATION
AWG-9RDR	83.9	649.0	19008	.0341	20000	70	3	RADAR
APX-72	AVG	16.5	479	.0344				RADIO COMM
APX-76A	AVG	19.0	726	.0262	170		1	RADIO COMM
ARC-51A	92.9	38.0	1300	.0292	180		2	RADIO COMM
ARC-159	AVG	9.0	173	.0520		74	3	RADIO COMM
ARR-69	78.5	10.0	318	.0315		65	2	RADIO COMM
ASW-27	AVG							RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARA-63	100.0	13.0				72	2	RADIO NAVIGATION
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-84	98.1	29.0	766	.0379	163	71	3	RADIO NAVIGATION

Table A-15 (Page 1 of 2)

F-15A DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-119	ECM System	Westinghouse Electric Corp. (Defense and Space Center)
ALQ-128	ECM Multimode	Magnavox Co.
ALQ-135	ECM Jamming	Northrop Corp.
ASK-6	Data Computer	Sperry Rand Corp.
CP-1075/AYK	Air Data Computer	IBM Corp.
AJN-18	Horizontal Situation Ind.	Rockwell Int. (Collins Radio)
ARU-39/A	Attitude Direction Ind.	Astronautics Corp.
AVQ-20	Head-Up Display	McDonnell Douglas Corp.
C-9011	CNI Displays	SCI
OI-60/A	Vertical Situation Disp.	Sperry Rand Corp.
AWG-20	Armament Control	McDonnell Douglas Corp.
Chaff/Flare	Chaff Dispenser (F-15)	Unknown
ASN-108	Attitude Reference	Sperry Rand Corp.
ASN-109	Inertial Navigation	Litton Industries (Guidance and Control Div.)
CN-1377/AWG	Computing Gyro	General Electric
ALQ-154	ECM Tail Warning	Cutler-Hammer (AIL Div.)
ALR-56	Radar Warning Receiver	Loral Electronics (Electronics Systems Div.)
APG-63	Radar Fire Control	Hughes Aircraft (Aerospace Group)
APX-76A	IFF Interrogator	Hazeltine Corp. (Electronic Div.)
APX-101	IFF Transponder	Teledyne
ARC-164	UHF/AM Radio	Magnavox Co.
MX-9147/APX	IFF Reply Evaluator	Litton Industries
MX-9287/A	Interference Blanker Sys.	McDonnell Douglas Corp.
ARN-112	Instrument Landing Sys.	Rockwell International
ARN-118	TACAN	Rockwell Int. (Collins Radio)
OA-8639/ARA	Automatic Direction Finder	Rockwell Int. (Collins Radio)
CNI Antenna	Com.Nav.Ident.Ant. (F-15)	Transco Products Inc. Rockwell Int. (Collins Radio) Dorne and Margolin Daico
KIR/1A/TSEC	Interrogator Computer	National Security Agency
KIT/1A/TSEC	Transponder Computer	National Security Agency
KY-28/TSEC	Secure Speech	National Security Agency
Mag.Azi.Det.	Mag. Azi. Det. (F-15)	Sperry Rand Corp.
T-1217/AR	Attack Sensor	Teledyne
Tot.Temp.Prb.	Total Temp. Probe (F-15)	Rosemount

Table A-15 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-119	AVG							ACTIVE ECM
ALQ-128	96.3	58.6	2765	.0212	168	76	3	ACTIVE ECM
ALQ-135	96.3	387.0	10368	.0373	8000	76	3	ACTIVE ECM
ASK-6	95.6	16.2	518	.0313	70			COMPUTER
CP-1075/AYK	93.1	41.5	1728	.0240	300	72	2	COMPUTER
AJN-18	108.2	16.0	518	.0309	36			DISPLAY
ARU-39/A	113.5	5.5	132	.0417	9			DISPLAY
AVQ-20	96.3	68.1	1935	.0352	316	76	2	DISPLAY
C-9011	102.8	23.0	605	.0380	40	72	3	DISPLAY
OD-60/A	88.8	43.0	1175	.0366	306			DISPLAY
AWG-20	114.0	49.3	2081	.0237	235			ELECTROMECHANICAL
Chaff/Flare	NONE	170.0	3456	.0492	90			ELECTROMECHANICAL
ASN-108	91.6	28.0	726	.0386	132	72	3	INERTIAL
ASN-109	93.3	50.6	1728	.0293	287			INERTIAL
CN-1377/AWG	99.9	18.4	915	.0201	27			INERTIAL
ALQ-154	NONE	80.0	2250	.0356	540			PASSIVE ECM
ALR-56	96.3	142.6	4164	.0342	680	76	3	PASSIVE ECM
APG-63	83.8	494.5	16934	.0292	10739	72	3	RADAR
APX-76A	AVG	19.0	726	.0262	170		1	RADIO COMM
APX-101	AVG	14.7	380	.0387	65		2	RADIO COMM
ARC-164	AVG	17.0	173	.0984	110			RADIO COMM
MX-9147/APX	75.7	18.0	657	.0274	85			RADIO COMM
MX-9287/A	NONE	7.2	250	.0288	65			RADIO COMM
ARN-112	97.7	6.8	207	.0329	16	72	2	RADIO NAVIGATION
ARN-118	AVG	44.0	2108	.0209	280			RADIO NAVIGATION
OA-8639/ARA	96.3	12.6	207	.0609	16			RADIO NAVIGATION
CNI Antenna	NONE	12.0			22			MISCELLANEOUS
KIR/1A/TSEC	NONE	13.1	276	.0475	35			MISCELLANEOUS
KIT/1A/TSEC	NONE	12.1	276	.0438	30			MISCELLANEOUS
KY-28/TSEC	NONE	16.0	440	.0364	30			MISCELLANEOUS
Mag.Azi.Det.	101.2	1.6	17	.0941				MISCELLANEOUS
T-1217/AR	94.6	3.9	53	.0736	310			MISCELLANEOUS
Tot.Temp.Prb.	NONE	2.2	7	.3143	400			MISCELLANEOUS

Table A-16 (Page 1 of 2)

F-111A DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-41	ECM	Sanders Associates
ALE-28	Chaff Dispenser	General Dynamics Corp. Lundy Electronics
AJQ-20	Inertial Bomb/Nav.	Litton Industries
AAR-34	Infrared Detecting Group	AVCO Corp. (Electronics Div.)
ALR-23	ECM IR Receiver	AVCO Corp.
ASG-23	Optical Sight	General Electric (Light Military Electronic Dept.)
APS-109A	Radar Homing/Warning	Textron (Bell Aerospace) Ling-Temco-Vought Inc./Raytheon
APN-167	Radar Altimeter	Honeywell Inc./ITT Corp.
APQ-110	Radar Terrain Following	Texas Instruments Inc.
APQ-113	Radar Attack	General Electric (Light Military Equipment Dept.)
APX-64V	IFF Transponder	Hazeltine Corp.
ARC-109V	UHF Transceiver	Rockwell Int. (Collins Radio)
ARC-123	HF Radio	AVCO Corp. (Electronics Div.)
MX-6770U	Interference Blanker Sys.	Unknown
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.) Republic Electronics
ARN-58A	Instrument Landing Sys.	Rockwell Int. (Collins Radio) Courter

Table A-16 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-41	85.2	207.0	5530	.0374	207	60	1	ACTIVE ECM
ALE-28	AVG	106.0				67		ELECTROMECHANICAL
AJQ-20	AVG	202.0	7085	.0285		65	2	INERTIAL
AAR-34	AVG	235.0	7539	.0311		65		OPTICAL
ALR-23	AVG	63.0	1693	.0372	90	67		OPTICAL
ASG-23	AVG							OPTICAL
APS-109A	AVG	99.0				67	2	PASSIVE ECM
APN-167	92.2	28.0	1849	.0151	90	65	2	RADAR NAVIGATION
APQ-110	AVG	237.0	8985	.0264	2000	65	2	RADAR
APQ-113	118.0	370.0	10714	.0345	1637	64	2	RADAR
APX-64V	AVG	29.0	2084	.0139	80		1	RADIO COMM
ARC-109V	89.3	30.0	997	.0301	232	72	2	RADIO COMM
ARC-123	AVG	91.0	4420	.0206				RADIO COMM
MX-6770U	AVG							RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-58A	AVG	19.0				70	1	RADIO NAVIGATION

Table A-17 (Page 1 of 2)

F-111D DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-87	ECM Pod Equipment	General Electric
ALQ-94	ECM	Sanders Associates
AYK-6	Digital Computer	IBM Corp.
AVA-9	Integrated Data Display	United Technologies (Norden)
AYN-4	Horizontal Situation Disp.	Astronautics Corp.
ALE-28	Chaff Dispenser	General Dynamics Corp. Lundy Electronics
AJN-16	Inertial Navigation	Rockwell Int.
AAR-34	Infrared Detecting Group	AVCO Corp. (Electronics Div.)
ALR-23	ECM IR Receiver	AVCO Corp.
ALR-41	ECM Receiver	Loral Electronics (Systems Div.) General Dynamics
APS-109A	Radar Homing/Warning	Textron (Bell Aerospace) Ling-Temco-Vought Inc./Rayethon
APN-167	Radar Altimeter	Honeywell Inc./ITT Corp.
APN-189	Radar Doppler	Canadian Marconi Co.
APQ-128	Radar Terrain Following	Texas Instruments Inc.
APQ-130	Radar Attack	Rockwell International (NAR)
APX-64V	IFF Transponder	Hazeltine Corp.
ARC-109V	UHF Transceiver	Rockwell Int. (Collins Radio)
ARC-123	HF Radio	AVCO Corp. (Electronics Div.)
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.) Republic Electronics
ARN-58A	Instrument Landing Sys.	Rockwell Int. (Collins Radio) Courter

Table A-17 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-87	AVG				3500			ACTIVE ECM
ALQ-94	93.6	400.0	13824	.0289		67		ACTIVE ECM
AYK-6	85.9	47.0	1437	.0327	240	67	3	COMPUTER
AVA-9	NONE							DISPLAY
AYN-4	AVG	60.0				67		DISPLAY
ALE-28	AVG	106.0				67		ELECTROMECHANICAL
AJN-16	90.0	85.0	4493	.0189		67	3	INERTIAL
AAR-34	AVG	235.0	7539	.0311		65		OPTICAL
ALR-23	AVG	63.0	1693	.0372	910	67		OPTICAL
ALR-41	85.2	207.0	5530	.0374	12			PASSIVE ECM
APS-109A	AVG	99.0				67	2	PASSIVE ECM
APN-167	92.2	28.0	1849	.0151	90	65	2	RADAR NAVIGATION
APN-189	NONE	59.5				67		RADAR NAVIGATION
APQ-128	94.6	237.0	8986	.0264	2000	67	2	RADAR
APQ-130	90.0	560.0			6000	68	2	RADAR
APX-64V	AVG	29.0	2084	.0139	80		1	RADIO COMM
ARC-109V	89.3	30.0	997	.0301	232	72	2	RADIO COMM
ARC-123	AVG	91.0	4420	.0206				RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-58A	AVG	19.0				70	1	RADIO NAVIGATION

Table A-18 (Page 1 of 2)

F-111E DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-87	ECM Pod Equipment	General Electric
ALQ-94	ECM	Sanders Associates
ALE-28	Chaff Dispenser	General Dynamics Corp. Lundy Electronics
AJQ-20	Inertial Bomb/Nav.	Litton Industries
AAR-34	Infrared Detecting Group	AVCO Corp. (Electronics Div.)
ALR-23	ECM IR Receiver	AVCO Corp.
ASG-23	Optical Sight	General Electric (Light Military Electronic Dept.)
ALR-41	ECM Receiver	Loral Electronics (Systems Div.) General Dynamics
APS-109A	Radar Homing/Warning	Textron (Bell Aerospace) Ling-Temco-Vought Inc./Raytheon
APN-167	Radar Altimeter	Honeywell Inc./ITT Corp.
APQ-110	Radar Terrain Following	Texas Instruments Inc.
APQ-113	Radar Attack	General Electric (Light Military Equipment Dept.)
APX-64V	IFF Transponder	Hazeltine Corp.
ARC-109V	UHF Transceiver	Rockwell Int. (Collins Radio)
ARC-123	HF Radio	AVCO Corp. (Electronics Div.)
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.) Republic Electronics
ARN-58A	Instrument Landing Sys.	Rockwell Int. (Collins Radio) Courter

Table A-18 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-87	AVG				3500			ACTIVE ECM
ALQ-94	93.6	400.0	13824	.0289		67		ACTIVE ECM
ALE-28	AVG	106.0				67		ELECTROMECHANICAL
AJQ-20	AVG	202.0	7085	.0285		65	2	INERTIAL
AAR-34	AVG	235.0	7539	.0311		65		OPTICAL
ALR-23	AVG	63.0	1693	.0372	910	67		OPTICAL
ASG-23	AVG							OPTICAL
ALR-41	85.2	207.0	5530	.0374	12			PASSIVE ECM
APS-109A	AVG	99.0				67	2	PASSIVE ECM
APN-167	92.2	28.0	1849	.0151	90	65	2	RADAR NAVIGATION
APQ-110	AVG	237.0	8985	.0264	2000	65	2	RADAR
APQ-113	118.0	370.0	10714	.0345	1637	64	2	RADAR
APX-64V	AVG	29.0	2084	.0139	80		1	RADIO COMM
ARC-109V	89.3	30.0	997	.0301	232	72	2	RADIO COMM
ARC-123	AVG	91.0	4420	.0206				RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-58A	AVG	19.0				70	1	RADIO NAVIGATION

Table A-19 (Page 1 of 2)

F-111F DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-87	ECM Pod Equipment	General Electric
ALQ-94	ECM	Sanders Associates
ALE-28	Chaff Dispenser	General Dynamics Corp. Lundy Electronics
AJN-16	Inertial Navigation	Rockwell Int.
AAR-34	Infrared Detecting Group	AVCO Corp. (Electronics Div.)
ALR-23	ECM IR Receiver	AVCO Corp.
ASG-27	Optical Sight	General Electric (Light Military Electronic Dept.)
ALR-41	ECM Receiver	Loral Electronics (Systems Div.) General Dynamics
APS-109A	Radar Homing/Warning	Textron (Bell Aerospace) Ling-Temco-Vought Inc./Rayethon
APN-167	Radar Altimeter	Honeywell Inc./IIT Corp.
APQ-128	Radar Terrain Following	Texas Instruments Inc.
APQ-144	Radar Bomb Delivery	General Electric
APX-64V	IFF Transponder	Hazeltine Corp.
ARC-109V	UHF Transceiver	Rockwell Int. (Collins Radio)
ARC-123	HF Radio	AVCO Corp. (Electronics Div.)
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.) Republic Electronics
ARN-58A	Instrument Landing Sys.	Rockwell Int. (Collins Radio) Courter

Table A-19 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-87	AVG				3500			ACTIVE ECM
ALQ-94	93.6	400.0	13824	.0289		67		ACTIVE ECM
ALE-28	AVG	106.0				67		ELECTROMECHANICAL
AJN-16	90.0	85.0	4493	.0189		67	3	INERTIAL
AAR-34	AVG	235.0	7539	.0311		65		OPTICAL
ALR-23	AVG	63.0	1693	.0372	90	67		OPTICAL
ASG-27	NONE							OPTICAL
ALR-41	85.2	207.0	5530	.0374	12			PASSIVE ECM
APS-109A	AVG	99.0				67	2	PASSIVE ECM
APN-167	92.2	28.0	1849	.0151	90	65	2	RADAR NAVIGATION
APQ-128	94.6	237.0	8986	.0264	2000	67	2	RADAR
APQ-144	AVG	370.0	10610	.0349	1637	70	2	RADAR
APX-64V	AVG	29.0	2084	.0139	80		1	RADIO COMM
ARC-109V	89.3	30.0	997	.0301	232	72	2	RADIO COMM
ARC-123	AVG	91.0	4420	.0206				RADIO COMM
ARA-50	AVG	7.0	346	.0202	45	65	2	RADIO NAVIGATION
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-58A	AVG	19.0				70	1	RADIO NAVIGATION

Table A-20 (Page 1 of 2)

FB-111A DATA AT THE SYSTEM LEVEL

DESIGNATOR	FUNCTION	MANUFACTURER
ALQ-94	ECM	Sanders Associates
AYK-6	Digital Computer	IBM Corp.
AYN-4	Horizontal Situation Disp.	Astronautics Corp.
ALE-28	Chaff Dispenser	General Dynamics Corp. Lundy Electronics
AJN-16	Inertial Navigation	Rockwell Int.
AAR-34	Infrared Detecting Group	AVCO Corp. (Electronics Div.)
ALR-23	ECM IR Receiver	AVCO Corp.
ASG-26	Optical Sight Lead Comp.	General Electric (Light Military Electronic Dept.)
ALR-41	ECM Receiver	Loral Electronics (Systems Div.) General Dynamics
ALR-62	Radar Homing/Warning	Textron Inc. (Dalmo Victor Div.)
APS-109A	Radar Homing/Warning	Textron (Bell Aerospace) Ling-Temco-Vought Inc./Raytheon
APN-185	Radar Navigation	Singer Co.
APQ-110	Radar Terrain Following	Texas Instruments Inc.
APQ-114	Radar Attack	General Electric/Sage Labs
APQ-134	Radar Terrain Following	Texas Instruments Inc.
APX-64V	IFF Transponder	Hazeltine Corp.
APX-78	Transponder	Motorola Inc.
ARC-109V	UHF Transceiver	Rockwell Int. (Collins Radio)
ARC-123	HF Radio	AVCO Corp. (Electronics Div.)
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.) Republic Electronics
ARN-58A	Instrument Landing Sys.	Rockwell Int. (Collins Radio) Courter
ASQ-119	Astrotracker	Litton Industries

Table A-20 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU. IN.	DENSITY LBS/ CU. IN.	POWER VA	TECHNO YR	TECHNO LVL	FUNCTIONAL GROUP
ALQ-94	93.6	400.0	13824	.0289		67		ACTIVE ECM
AYK-6	85.9	47.0	1437	.0327	240	67	3	COMPUTER
AYN-4	AVG	60.0				67		DISPLAY
ALE-28	AVG	106.0				67		ELECTROMECHANICAL
AJN-16	90.0	85.0	4493	.0189		67	3	INERTIAL
AAR-34	AVG	235.0	7539	.0311		65		OPTICAL
ALR-23	AVG	63.0	1693	.0372	910	67		OPTICAL
ASG-26	AVG							OPTICAL
ALR-41	85.2	207.0	5530	.0374	12			PASSIVE ECM
ALR-62	NONE							PASSIVE ECM
APS-109A	AVG	99.0				67	2	PASSIVE ECM
APN-185	90.1	65.0	5218	.0125	325	67	2	RADAR NAVIGATION
APQ-110	AVG	237.0	8985	.0264	2000	65	2	RADAR
APQ-114	75.0	370.0	10610	.0349	1637	67	2	RADAR
APQ-134	94.5	237.0	8986	.0264	2000	66	2	RADAR
APX-64V	AVG	29.0	2084	.0139	80		1	RADIO COMM
APX-78	AVG	6.0	121	.0496			2	RADIO COMM
ARC-109V	89.3	30.0	997	.0301	232	72	2	RADIO COMM
ARC-123	AVG	91.0	4420	.0206				RADIO COMM
ARN-52	92.3	51.0	2305	.0221	420	64	1	RADIO NAVIGATION
ARN-58A	AVG	19.0				70	1	RADIO NAVIGATION
ASQ-119	AVG	66.0	3629	.0182		67	2	MISCELLANEOUS

Appendix B

SYSTEMS LEVEL COST ESTIMATING DATA

This appendix presents data underlying Section IV's analysis of systems level avionics costs. Table B-1 displays the summary statistics for all the 223 systems contained in the sample. For the principal parameters, the listing supplies the number of cases affected and the means and standard deviations of the distributions. To obtain values for individual systems consult the specifications embodied in the functional group inventories which follow. Proprietary reasons prevent the recording of cost by equipment item.

Tables B-2 through B-14 deal with the 13 functional groups. For each system within a particular functional group, the first segment of each table gives a description of the system, the prime and second-source producer and division, and the aircraft affiliation. The second segment indicates the systems' technical characteristics and, except for power management and miscellaneous, the functional group's summary statistics.

For reference, the tables are identified below:

Table	Title
B-1	All Systems' Summary Statistics
B-2	Active Electronic Countermeasures Group Data
B-3	Computers Group Data
B-4	Displays Group Data
B-5	Electromechanical Devices Group Data
B-6	Inertial Systems Group Data

Table B-1

ALL SYSTEMS' SUMMARY STATISTICS

Variable Description (unit of measure)	Variable Name	Number of Cases	Mean of Distribution	Standard Deviation of Distribution
Lot and non-lot related cost (K$)	COST	198	107.4288	180.3162
Lot related cost at 100th unit (K$)	COST100	113	125.3478	214.7294
Lot and non-lot related cost per pound (K$)	COSTLB	170	1.1419	1.1878
Lot related cost per pound at 100th unit (K$)	CSTLB100	111	1.1513	0.9824
Lot related learning curve (%)	CURVE	113	92.0593	9.7012
Weight (lb)	WEIGHT	180	121.6511	185.9641
Volume (cu in.)	VOLUME	150	4860.2067	8491.2568
Density (lb/cu in.)	DENSITY	150	0.0341	0.0288
Input power (volt amperes)	POWER	128	1215.7656	2763.1233
Year of introduction	YEAR	119	67.3950	4.0739
Vacuum tube technology (yes = 1, no = 0)	VACUUM	109	0.2385	0.4282
Solid state technology (yes = 1, no = 0)	SOLID	109	0.5780	0.4962
Integrated circuit technology (yes = 1, no = 0)	INTGRTD	109	0.1835	0.3889

Table B-2 (Page 1 of 2)

ACTIVE ELECTRONIC COUNTERMEASURES GROUP DATA

ACTIVE ECM SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ALQ-41	ECM	Sanders Associates											X						
ALQ-49	ECM	Sanders Associates																	
ALQ-51	ECM	Sanders Associates																	
		Raytheon (Space and Info. Systems Div.)																	
ALQ-51A	ECM	Sanders Associates																	
ALQ-55	ECM	Sanders Associates																	
ALQ-71	ECM	Hughes Aircraft							X										
ALQ-75	ECM	General Electric (Light Military Electronics Dept.)						X											
ALQ-76	ECM	Raytheon/McDonnell Douglas																	
ALQ-81	ECM	Sanders Associates																	
ALQ-87	ECM Pod Equipment	General Electric			X									X	X	X			
ALQ-88	ECM	Sanders Associates																	
ALQ-91	ECM	Magnavox Co.									X								
ALQ-92	ECM	Sanders Associates																	
ALQ-94	ECM	Sanders Associates												X	X	X	X		
ALQ-100	ECM	Sanders Associates	X	X	X	X		X			X							X	
ALQ-119	ECM System	Westinghouse Electric Corp. (Defense and Space Center)								X									X
ALQ-120	ECM	Sanders Associates				X													
ALQ-126	ECM	Sanders Associates				X					X							X	
ALQ-128	ECM Multimode	Magnavox Co.																X	X
ALQ-135	ECM Jamming	Northrop Corp.																	X

Table B-2 (Page 2 of 2)

ACTIVE ECM SYSTEMS																								
						TECHNO		AIRCRAFT																
DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	YR	LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ALQ-41	85.2	207.0	5530	.0374	207	60	1											X						
ALQ-49	AVG	155.0	4493	.0345		63	1																	
ALQ-51	100.1	128.0	4147	.0309	220	61	1																	
ALQ-51A	99.2	127.0	3750	.0339	220	66	1																	
ALQ-55	AVG	290.0	8640	.0336		63	1																	
ALQ-71	NONE				3500									X										
ALQ-75	NONE				11300								X											
ALQ-76	AVG	800.0			2500																			
ALQ-81	AVG	487.0	12165	.0400	7900	68	2																	
ALQ-87	AVG				3500					X									X	X	X			
ALQ-88	97.5	470.0	12165	.0386	790	67	2																	
ALQ-91	AVG	50.0	1296	.0386		67	3									X								
ALQ-92	89.0	400.0	17280	.0232	780	68	2																	
ALQ-94	93.6	400.0	13824	.0289		67													X	X	X	X		
ALQ-100	93.4	220.0	3974	.0554	3800	65	3	X	X	X	X		X			X							X	
ALQ-119	AVG														X									X
ALQ-120	NONE										X													
ALQ-126	93.4	185.0	3974	.0466		72	3				X					X							X	
ALQ-128	96.3	58.6	2765	.0212	168	76	3																X	X
ALQ-135	96.3	387.0	10368	.0373	8000	76	3																	X

VARIABLE	CASES	MEAN	STD DEV
COST	17	182.4941	144.4245
COST100	9	219.3889	182.1850
COSTLN	15	0.7801	0.4057
CSTLN100	9	0.7780	0.3955
CURVE	9	93.8667	4.5166
WEIGHT	15	290.9733	201.7604
VOLUME	14	7.4643K	4.9052K
DENSITY	14	0.0359	0.0088
POWERIN	13	3298.8462	3642.5650
POWEROUT	12	1.8333	1.5275
MAXFREQ	12	7.4971	5.1500
BANDWTH	6	3.2200	3.0424
MINFREQ	12	2.7967	2.7917
[illegible]	7	110.2557	181.4577
YEAR	14	67.0714	4.8906
VACUUM	13	0.3846	0.5064
SOLID	13	0.2308	0.4385
INTGRTD	13	0.3846	0.5064

NOTE: The learning curve column contains the following information: a percentage if costs derive from specific production lot data, "AVG" if costs relate only to last-lot-average costs, and "NONE" if costs are unavailable. The technology level column's numerical codes decipher as 1 if vacuum tubes, 2 if transistors, and 3 if integrated circuits predominate the electronics.

Table B-3 (Page 1 of 2)

COMPUTERS GROUP DATA

COMPUTER SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AJB-3A	Loft Bomb Computer	Texas Instruments Inc. (Apparatus Div.)				X													
AJB-7	Loft Bomb Computer	Lear Seigler Inc. (Instrument Div.) Lear Siegler Inc. (Instrument Div.)	X					X	X	X	X								
AWA-157	Fire Control Group	Raytheon						X	X										
ASK-6	Data Computer	Sperry Rand Corp.																	X
ASN-39	Navigation Computer	Bendix Corp.									X								
ASN-41	Navigation Computer	Singer Co. (Gen. Perc. Inst.)	X																
ASN-46A	Navigation Computer	Bendix Corp. (Navigation and Control Div.)						X	X	X									
ASN-91	TAC Computer	IBM Corp. (Federal Systems Div.)			X	X													
ASQ-61	Ballistics Computer	Litton Industries (Guidance and Control Div.)																	
ASQ-91	Bomb Computer	Littor Industries							X	X									
ASQ-133	Ballistic Computer	IBM Corp. (Federal Systems Div.)		X															
ASQ-155	Ballistic Computer	IBM Corp./Fairchild Industries		X															
AWG-9CCMP.	Computer	Hughes Aircraft																X	
AYK-6	Digital Computer	IBM Corp.												X			X		
CP-1005A	Air-Data Computer	Conrac		X															
CP-1035A	Air Data Computer	Garrett Airesearch Co.																X	
CP-1075/AYK	Air Data Computer	IBM Corp.																	X
CPU-80A	Flight Direction Computer	Unknown			X														
CSDC	Signal Converter (F-14)	Teledyne																	
CSV-80	Flight Direction Computer	Unknown					X												

Table B-3 (Page 2 of 2)

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	TECHNO LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AJB-3A	83.4	83.0	3454	.0240	245	64	1				X													
AJB-7	80.7	70.0	2102	.0333	407	64	1	X					X	X	X	X								
APA-157	61.5	233.0			3000		1						X	X										
ASK-6	95.6	16.2	518	.0313	70																			X
ASN-39	77.9	25.0				61	2									X								
ASN-41	95.7	32.0					2	X																
ASN-46A	AVG	31.0	831	.0373	85	65	2						X	X	X									
ASN-91	89.0	80.0	2592	.0309	325	67	2			X	X													
ASQ-61	82.8	190.0	9683	.0196		60	2																	
ASQ-91	107.5	41.0	1409	.0291	120	69	2							X	X									
ASQ-133	86.0	176.0	1537	.1145	260	70	2		X															
ASQ-155	94.5	69.0	4666	.0148	160	70	2		X															
AWG-9COMP	85.6	175.0	5108	.0343	1000	70	2																X	
AYK-6	85.9	47.0	1437	.0327	240	67	3												X			X		
CP-1005A	94.9	50.4	1037	.0486	70	70	2		X															
CP-1035A	97.2	33.2	691	.0481	206	70	2																X	
CP-1075/AYK	93.1	41.5	1728	.0240	300	72	2																	X
CPU-80A	AVG									X														
CSDC	111.5	41.2	1412	.0292	200	71	2																	
CSV-80	AVG	6.8	204	.0333	42							X												

VARIABLE	CASES	MEAN	STD DEV
COST	20	113.1750	145.6167
COST100	17	130.4900	151.8915
COSTLB	19	1.5163	0.9521
CSTLB100	17	1.5753	0.9885
CURVE	17	89.5765	11.5345
WEIGHT	19	75.8579	66.4483
VOLUME	16	2400.5625	2400.4609
DENSITY	16	0.0366	0.0226
POWER	16	420.6250	723.7365
YEAR	15	67.3333	3.7353
VACUUM	17	0.1765	0.3930
SOLID	17	0.7647	0.4372
INTGRTD	17	0.0588	0.2425

Table B-4 (Page 1 of 2)

DISPLAYS GROUP DATA

DISPLAY SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AJN-18	Horizontal Situation Ind.	Rockwell Int. (Collins Radio)																	X
ACU-6	Horizontal Situation Ind.	Unknown			X														
ARU-39/A	Attitude Direction Ind.	Astronautics Corp.																	X
ASA-79	Multi Mode Display	IBM Corp.																X	
ASN-67	Navigation System	Unknown																	
ASN-99	Projected Map Display	Control Data Corp.			X	X													
		(Computing Devices of Canada)																	
AVA-1	Vertical Display Indicator	Kaiser Industries Corp.		X															
AVA-9	Integrated Data Display	United Technologies (Norden)												X					
AVA-12	Vertical/Head-Up Display	Kaiser Industries Corp.																X	
AVQ-7	Head-Up Display	EA Industrial Corp./Elliot Bros.			X	X													
AVQ-20	Head-Up Display	McDonnell Douglas Corp.																	X
AWG-9DISP.	Displays	Hughes Aircraft																X	
AYN-4	Horizontal Situation Disp.	Astronautics Corp.												X			X		
C-9011	CNI Displays	SCI																	X
Head-Up Dspl	Head-Up Display (A-10)	McDonnell Douglas Corp.					X												
		Kaiser Industries																	
ID-1744A	Data Indicator	Huyck Corp. (Hartman Systems)																	
OC-60/A	Vertical Situation Disp.	Sperry Rand Corp.																	X
TV Monitor	TV Monitor (A-10)	Cardion Electronics					X												

Table B-4 (Page 2 of 2)

DISPLAY SYSTEMS						TECHNO		AIRCRAFT																
DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	YR	LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AJN-18	108.2	16.0	518	.0309	36																			X
AQU-6	AVG									X														
ARU-39/A	113.5	5.5	132	.0417	9																			X
ASA-79	88.9	62.9	3231	.0195	505	70	2																X	
ASN-67	AVG	70.0																						
ASN-99	101.9	42.0				68	2			X	X													
AVA-1	103.6	27.0	1106	.0244		70			X															
AVA-9	NONE																		X					
AVA-12	85.5	121.0	5357	.0226	810	70	1																X	
AVQ-7	AVG	84.0				67				X	X													
AVQ-20	96.3	68.1	1935	.0352	316	76	2																	X
AWG-9DISP	AVG																						X	
AYN-4	AVG	60.0				67													X			X		
C-9011	102.8	23.0	605	.0380	40	72	3																	X
Head-UP DSPL	111.5	65.2	4755	.0137	365							X												
ID-1744A	87.8	4.6	153	.0301	29	70	2																	
OD-60/A	88.8	43.0	1175	.0366	306																			X
TV Monitor	84.0	17.0	431	.0394	155							X												

VARIABLE	CASES	MEAN	STD DEV
COST	17	63.1765	63.4455
COST100	12	52.1000	51.0799
COSTLB	15	1.2653	0.7258
CSTLB100	12	1.2217	0.3971
CURVE	12	97.7333	10.5397
WEIGHT	15	47.2867	32.6989
VOLUME	11	1763.4545	1864.0915
DENSITY	11	0.0302	0.0091
POWER	10	257.1000	259.2041
YEAR	9	70.0000	2.7839
VACUUM	6	0.1667	0.4082
SOLID	6	0.6667	0.5164
INTGRTD	6	0.1667	0.4082

Table B-5 (Page 1 of 2)

ELECTROMECHANICAL DEVICES GROUP DATA

ELECTROMECHANICAL DEVICES			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ALE-18	Chaff Dispenser	Applied Science Industries Lundy Electronics																	
ALE-28	Chaff Dispenser	General Dynamics Corp. Lundy Electronics											X	X	X	X	X		
ALE-29	Chaff Dispenser	Tracor Inc.	X	X		X					X							X	
ALE-32	Chaff Dispenser	Lundy Electronics		X															
ALE-39	Chaff Dispenser	Goodyear Aerospace				X												X	
ALE-40(V)	Chaff Dispenser	Tracor Inc.					X												
AWE-1	Weapons Release	Bendix Corp. (Navigation and Control Div.)	X																
AWG-9MSLAUX	Missile Aux.	Hughes Aircraft																X	
AWG-15	Fire Control System	Fairchild Industries																X	
AWG-17	Armament Control System	Dyramic Controls Corp.																	
AWG-20	Armament Control	McDonnell Douglas Corp.																	X
AWW-1	Fuse Function Control	Rauland Borg Co.									X								
AWW-2	Bomb Fuse Control	Polyphase Instruments			X	X													
AWW-4	Fuze Control	Unknown	X	X		X													
AWW-5	Fuse Control	General Dynamics Corp.																X	
Arm.Cont.Sys.	Armament Cont. Sys. (A-10)	Fairchild Industries					X												
Chaff/Flare	Chaff Dispenser (F-15)	Unknown																	X

Table B-5 (Page 2 of 2)

ELECTROMECHANICAL DEVICES																								
						TECHNO		AIRCRAFT																
DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	YR	LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ALE-18	89.8	31.0																						
ALE-28	AVG	106.0				67												X	X	X	X	X		
ALE-29	79.2	43.0	1398	.0308	28		2	X	X		X					X							X	
ALE-32	AVG								X															
ALE-39	AVG	36.0									X												X	
ALE-40(V)	AVG	186.0										X												
AWE-1	105.8	9.0	408	.0221	5	66	1	X																
AWG-9Msl Aux.	AVG																						X	
AWG-15	88.0	46.7	2347	.0199	102	70	2																X	
AWG-17	90.7	47.0	2122	.0222	235	72	2																	
AWG-20	114.0	49.3	2081	.0237	235																			X
AWW-1	AVG	17.0	824	.0206			1									X								
AWW-2	AVG									X	X													
AWW-4	AVG							X	X		X													
AWW-5	NONE																						X	
Arm.Cont.Sys.	93.6											X												
Chaff/Flare	NONE	170.0	3456	.0492	90																			X

VARIABLE	CASES	MEAN	STD DEV
COST	15	57.9667	118.7308
COSTI00	7	30.4286	27.3953
COSTLB	10	0.7130	0.5784
CSTLB100	6	0.7067	0.5718
CURVE	7	94.4429	11.7018
WEIGHT	11	67.3636	60.0932
VOLUME	7	1805.1429	1022.7291
DENSITY	7	0.0269	0.0105
POWER	6	115.8333	99.2561
YEAR	4	68.7500	2.7538
VACUUM	5	0.4000	0.5477
SOLID	5	0.6000	0.5477
INTGRTD	5	0.0	0.0

Table B-6 (Page 1 of 2)

INERTIAL SYSTEMS GROUP DATA

INERTIAL SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AJN-16	Inertial Navigation	Rockwell Int.												X		X	X		
AJQ-20	Inertial Bomb/Nav.	Litton Industries											X		X				
ASN-31	Intertial Navigation	Littor Industries (Guidance and Control Div.)		X															
ASN-48	Inertial Navigation	Litton Industries (Guidance and Control Div.)						X											
ASN-50	Attitude/Heading	Lear Siegler Inc. Texas Instruments Inc. Martin-Marietta Corp.																	
ASN-56	Inertial Navigation	Littor Industries (Guidance and Control Div.)																	
ASN-63	Inertial Navigation	Littor Industries (Guidance and Control Div.)							X	X									
ASN-70	Vertical Reference	Lear Siegler Inc.																	
ASN-90	Inertial Measurement	Singer Co. (Kearfott Div.)			X	X													
ASN-92	Inertial Navigation	Littor Industries (Guidance and Control Div.)		X														X	
ASN-108	Attitude Reference	Sperry Rand Corp.																	X
ASN-109	Inertial Navigation	Littor Industries (Guidance and Control Div.)																	X
CN-1377/AWG	Computing Gyro	General Electric																	X
LSI6000A	Attitude Reference	Lear Siegler Inc.					X												

Table B-6 (Page 2 of 2)

INERTIAL SYSTEMS																								
						TECHNO		AIRCRAFT																
DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	YR	LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AJN-16	90.0	85.0	4493	.0189		67	3												X		X	X		
AJQ-20	AVG	202.0	7085	.0285		65	2											X		X				
ASN-31	80.0	130.0				60	1		X															
ASN-48	94.6	95.0	4147	.0229		60	1						X											
ASN-50	91.3					65																		
ASN-56	94.7	100.0	5304	.0189		66	1																	
ASN-63	96.3	95.0	4147	.0229		66								X	X									
ASN-70	95.4	44.0				66																		
ASN-90	87.7	70.0	1728	.0405		67	2			X	X													
ASN-92	AVG	123.9	4493	.0276					X														X	
ASN-108	91.6	28.0	726	.0386	132	72	3																	X
ASN-109	93.3	50.6	1728	.0293	287																			X
CN-1377/AWG	99.9	18.4	915	.0201	127																			X
LSI6000A	113.2	27.0	761	.0355	84							X												

VARIABLE	CASES	MEAN	STD DEV
COST	14	157.2357	173.9482
COST100	12	133.5333	155.8435
COSTLB	13	1.9623	1.6232
CSTLB100	11	2.0209	1.7319
CURVE	12	94.0000	7.8438
WEIGHT	13	82.2231	51.3889
VOLUME	11	3229.7273	2151.0887
DENSITY	11	0.0276	0.0078
POWER	4	157.5000	88.9813
YEAR	10	65.4000	3.4705
CEP	5	2.1000	1.2942
VACUUM	7	0.4286	0.5345
SOLID	7	0.2857	0.4880
INTGRTD	7	0.2857	0.4880

Table B-7 (Page 1 of 2)

OPTICAL SYSTEMS GROUP DATA

OPTICAL SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AAA-4	Infrared Detecting Group	ACF																	
AAR-34	Infrared Detecting Group	AVCO Corp. (Electronics Div.)											X	X	X	X	X		
AAS-35	Laser Search Tracker	Martin Marietta Corp.					X												
ALR-23	ECM IR Receiver	AVCO Corp.											X	X	X	X	X	X	
ASG-22	Optical Sight Lead Comp.	General Electric (Light Military Electronic Dept.)							X										
ASG-23	Optical Sight	General Electric (Light Military Electronic Dept.)											X		X				
ASG-25	Optical Fire Control	General Electric (Light Military Electronic Dept.)																	
ASG-26	Optical Sight Lead Comp.	General Electric (Light Military Electronic Dept.)								X							X		
ASG-27	Optical Sight	General Electric (Light Military Electronic Dept.)														X			
ASG-29	Optical Sight Lead Comp.	General Electric										X							
ASX-1	Target Identification	Northrop Corp. (Electro-Mechanical Div.)																	
AVG-8	Target Acquisition	Honeywell Inc.									X								
AVQ-9	Laser Designator	Martin-Marietta Corp.							X										
AVQ-10	Laser Illuminator	Ford Aerospace																	
AVQ-23	Designator	Westinghouse Electric Corp. (Aerospace Div.)								X									
AWG-9IR	Infrared Sensor	Hughes Aircraft																X	

Table B-7 (Page 2 of 2)

OPTICAL SYSTEMS								AIRCRAFT																
						TECHNO																		
DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	YR	LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AAA-4	AVG	41.0			298																			
AAR-34	AVG	235.0	7539	.0311		65												X	X	X	X	X		
AAS-35	AVG	56.2	2531	.0222	523							X												
ALR-23	AVG	63.0	1693	.0372	910	67												X	X	X	X	X	X	
ASG-22	AVG													X										
ASG-23	AVG																	X		X				
ASG-25	NONE																							
ASG-26	AVG														X							X		
ASG-27	NONE																				X			
ASG-29	AVG																X							
ASX-1	90.0	49.0	1495	.0328	300	75	2																	
AVG-8	98.9	25.0				71										X								
AVQ-9	AVG	10.0	858	.0117										X										
AVQ-10	AVG	600.0	54739	.0110		70																		
AVQ-23	AVG														X									
AWG-9IR	AVG	66.0	1901	.0347																			X	

VARIABLE	CASES	MEAN	STD DEV
COST	14	110.1357	138.5418
COST100	2	87.1500	72.6199
COSTLB	9	2.4156	3.2118
CSTLB100	2	2.1250	0.9829
CURVE	2	94.4500	6.2932
WEIGHT	9	127.2444	189.0090
VOLUME	7	10108.0000	19806.7758
DENSITY	7	0.0258	0.0109
POWER	4	507.7500	288.2387
YEAR	5	69.6000	3.8471
VACUUM	1	0.0	***************
SOLID	1	1.0000	***************
INTGRTD	1	0.0	***************

Table B-8 (Page 1 of 2)

PASSIVE ELECTRONIC COUNTERMEASURES GROUP DATA

PASSIVE ECM SYSTEMS

DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
			AIRCRAFT																
ALQ-154	ECM Tail Warning	Cutler-Hammer (AIL Div.)																	X
ALR-15	ECM Receiver	American Electronics Lab.																	
ALR-25	ECM	Sanders Associates Ling-Temco-Vought Inc./Rayethon																X	
ALR-26	ECM Receiver	Ling-Temco-Vought Inc.																	
ALR-31	ECM Receiver	Loral Electronics						X											
ALR-41	ECM Receiver	Loral Electronics (Systems Div.) General Dynamics												X	X	X	X		
ALR-45	Radar Homing/Warning	Itek Corp. (Applied Technology Div.)	X	X		X					X							X	
ALR-46	Radar Homing/Warning	Itek Corp. (Applied Technology Div.)																	
ALR-50	Radar Warning Receiver	Magnavox Co.	X	X	X	X					X							X	
ALR-56	Radar Warning Receiver	Loral Electronics (Electronics Systems Div.)																	X
ALR-62	Radar Homing/Warning	Textron Inc. (Dalmo Victor Div.)															X		
ALR-69V	Radar Warning Receiver	Itek Corp.					X												
ALT-34	ECM	Borders Electronics General Electric							X										
AER-25	Radar Homing/Warning	Itek Corp. (Applies Technology Div.)	X	X		X		X			X							X	
AER-27	Radar Receiver	Magnavox Co.	X	X		X					X							X	
APR-36	Radar Warning Receiver	Itek Corp.			X					X									
AEP-37	Radar Warning Receiver	Itek Corp.			X					X									
APR-38	Radar Homing/Warning	IBM Corp. (Federal Systems Div.)							X										
APS-107D	Radar Homing/Warning	Bendix Corp. (Electrodynamics Div.)							X										
APS-109A	Radar Homing/Warning	Textron (Bell Aerospace) Ling-Temco-Vought Inc./Rayethor											X	X	X	X	X		

Table B-8 (Page 2 of 2)

PASSIVE ECM SYSTEMS																								
						TECHNO		AIRCRAFT																
DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	YR	LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ALQ-154	NONE	80.0	2250	.0356	540																			X
ALR-15	74.4	1.4	14	.1000	34		1																	
ALR-25	NONE																						X	
ALR-26	AVG				58																			
ALR-31	NONE												X											
ALR-41	85.2	207.0	5530	.0374	12														X	X	X	X		
ALR-45	AVG	46.0				72		X	X		X					X							X	
ALR-46	AVG	55.0	1313	.0420	350	75	3																	
ALR-50	AVG	16.0				72		X	X	X	X					X							X	
ALR-56	96.3	142.6	4164	.0342	680	76	3																	X
ALR-62	NONE																					X		
ALR-69V	AVG	98.5	1690	.0583	885							X												
ALT-34	NONE				840									X										
APR-25	87.2	37.0	1538	.0241	74	66	2	X	X		X		X			X							X	
APR-27	86.6	11.0	760	.0145	420	66	1	X	X		X					X							X	
APR-36	AVG	38.0				67				X					X									
APR-37	AVG					67				X					X									
APR-38	AVG					74	3							X										
APS-107D	96.8	42.5	2004	.0212		70	3							X										
APS-109A	AVG	99.0				67	2											X	X	X	X	X		

VARIABLE	CASES	MEAN	STD DEV
COST	15	68.3800	73.7909
COST100	6	54.7500	90.2995
COSTLB	12	0.9858	0.7408
CSTLB100	6	0.9367	0.9254
CURVE	6	87.7500	8.2626
WEIGHT	13	67.2308	58.0707
VOLUME	9	2140.3333	1706.3257
DENSITY	9	0.0408	0.0256
POWER	10	389.3000	339.3327
YEAR	11	70.1818	3.7899
VACUUM	8	0.2500	0.4629
SOLID	8	0.2500	0.4629
INTGRTD	8	0.5000	0.5345

Table B-9 (Page 1 of 2)

POWER MANAGEMENT SYSTEMS GROUP DATA

POWER MANAGEMENT SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ASQ-19B	Integrated Electr. Central	Rockwell Int. (Collins Radio)						X	X	X	X								
ASQ-57	Integrated Electr. Central	Rockwell Int. (Collins Radio)		X															
ASQ-85	Integrated Electr. Central	RCA																X	

Table B-10 (Page 1 of 2)

RADARS GROUP DATA

RADAR SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
APG-53	Radar Fire Control	Stewart-Warner Corp. (Electronics Div.)	X																
APG-63	Radar Fire Control	Hughes Aircraft (Aerospace Group)																	X
APQ-72	Radar Control/Intercept	Westinghouse Electric Corp. (Air Arm Div.)																	
APQ-88	Radar Tracking/Terrain Map	United Technologies (Norden)																	
APQ-92	Radar Search	Uriter Technologies (Norden)																	
APQ-99	Radar Set Group	Texas Instruments Inc.																	
APQ-100	Radar Control/Intercept	Westinghouse Electric Corp. (Aerospace Div.)						X											

Table B-10 (Page 2 of 2)

	RADAR SYSTEMS							AIRCRAFT																
						TECHNO																		
DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	YR	LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
APG-53	71.6	90.0	6394	.0141	400	57	1	X																
APG-63	83.8	494.5	16934	.0292	10739	72	3																	X
APQ-72	77.0	619.0	60480	.0102	5800	58	1																	
APQ-88	86.4	305.0																						
APQ-92	82.6	532.0	21600	.0246	4000	60																		
APQ-99	94.4	222.0	15552	.0143	1550	62																		
APQ-100	AVG	856.0	26611	.0322	3600	62	1						X											
APQ-109	AVG	866.0	27302	.0317	3600	64	1							X										
APQ-110	AVG	237.0	8985	.0264	2000	65	2											X		X		X		
APQ-113	118.0	370.0	10714	.0345	1637	64	2											X		X				
APQ-114	75.0	370.0	10610	.0349	1637	67	2															X		
APQ-116	94.7	187.0	10022	.0187	1900	65																		
APQ-120	88.3	667.0	21082	.0316	3410	67	2								X									
APQ-126	AVG	230.0	20736	.0111	2200	67	2			X	X													
APQ-128	94.6	237.0	8986	.0264	2000	67	2												X		X			
APQ-130	90.0	560.0			6000	68	2												X					
APQ-134	94.5	237.0	8986	.0264	2000	66	2															X		
APQ-144	AVG	370.0	10610	.0349	1637	70	2														X			
APQ-148	AVG	365.0							X															
APQ-153	89.2	111.0	5875	.0189	800	71	2										X							
AWG-9RDR	83.9	649.0	19008	.0341	20000	70	3																X	
AWG-10	85.1	1180.0	33696	.0350	13000	64	2									X								

VARIABLE	CASES	MEAN	STD DEV
COST	22	346.2036	357.7941
COST100	16	369.4374	406.0840
COSTLB	22	0.7664	0.5772
CSTLB100	16	0.8162	0.6247
CURVE	16	88.0087	10.6791
WEIGHT	22	443.3864	276.3293
VOLUME	19	18114.8947	12911.8336
DENSITY	19	0.0257	0.0086
POWERIN	20	4395.5000	4881.7470
POWEROUT	21	80265.7143	53688.1205
ANTGAIN	21	32.9333	4.2544
SENSIVITY	20	54387.5500	219146.7186
PWMIN	21	0.3105	0.1434
PWMAX	21	10.4500	24.5235
PRF	21	3.2657	2.1941
YEAR	20	65.3000	4.0924
VACUUM	17	0.1765	0.3930
SOLID	17	0.7059	0.4697
INTGRTD	17	0.1176	0.3321

Table B-11 (Page 1 of 2)

RADAR NAVIGATION SYSTEMS GROUP DATA

RADAR NAVIGATION SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
APN-122	Radar Doppler Navigation	Teledyne (Ryan Aeronautical Div.)																	
APN-141	Radar Electronic Altimeter	Bendix Corp. (Pacific Div.)	X		X	X					X								
APN-153	Radar Doppler Navigation	Labs For Electronics Singer Co. (GPL Div.) Loral Electronics (Electronics Systems Div.)	X	X															
APN-154V	Radar Beacon	Motorola Inc. (Military Electronics Div.) United Telecontrol	X	X	X						X							X	
APN-155	Radar Altimeter	RCA (Defense Electronics Prod.Div.) Stewart-Warner Corp. (Electronics Div.)						X	X	X									
APN-167	Radar Altimeter	Honeywell Inc./ITT Corp.											X	X	X	X			
APN-185	Radar Navigation	Singer Co.															X		
APN-187	Radar Doppler	Singer Co. (Kearfott Div.)												X					
APN-189	Radar Doppler	Canadian Marconi Co.																	
APN-190	Radar Doppler	Singer Co. (Kearfott Div.)			X	X													
APN-194	Radar Electronic Altimeter	Honeywell Inc. (GAP Div.)	X	X		X					X							X	
APN-200	Doppler Velocity Sensor	Teledyne (Ryan Aeronautical Div.)																	

Table B-11 (Page 2 of 2)

RADAR NAVIGATION SYSTEMS

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	TECHNO LVL	A-9M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
APN-122	85.5	34.0	12400	.0027	749	61	2																	
APN-141	83.5	11.4	156	.0731		64	2	X		X	X					X								
APN-153	74.3	53.0	3629	.0146	425	63	2	X	X															
APN-154V	85.7	6.0	190	.0316		66	2	X	X	X						X							X	
APN-155	AVG	19.0	691	.0275	80	69	2						X	X	X									
APN-167	92.2	28.0	1849	.0151	90	65	2											X	X	X	X			
APN-185	90.1	65.0	5218	.0125	325	67	2															X		
APN-187	AVG	42.0	2782	.0151	175		3																	
APN-189	NONE	59.5				67													X					
APN-190	AVG	65.0	5478	.0119		67	2			X	X													
APN-194	98.1	7.0			400	70		X	X		X					X							X	
APN-200	AVG	44.0	3456	.0127	120		2																	

VARIABLE	CASES	MEAN	STD DEV
COST	11	47.9000	53.6181
COST100	7	35.0429	46.0298
COSTLB	11	1.3900	1.2996
CSTLB100	7	1.2500	1.2442
CURVE	7	87.0571	7.4980
WEIGHT	12	36.1583	22.0044
VOLUME	10	3584.9000	3640.6768
DENSITY	10	0.0217	0.0198
POWER	8	295.5000	229.3513
YEAR	10	65.9000	2.7264
VACUUM	10	0.0	0.0
SOLID	10	0.9000	0.3162
INTGRTD	10	0.1000	0.3162

Table B-12 (Page 1 of 2)

RADIO COMMUNICATION SYSTEMS GROUP DATA

RADIO COMMUNICATION SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AIC-14	Intercom	West Electronics		X															
		Monmouth Electric Co.																	
AIC-18	Intercom	Ardrea Radio Corp.					X					X							
AIC-25	Intercom	Andrea Radio Corp.				X													
		Melcor Electronics Corp.																	
		Monmouth Electric Co.																	
APX-64V	IFF Transponder	Hazeltine Corp.											X	X	X	X	X		
APX-72	IFF Transponder	Bendix Corp. (Radio Div.)	X	X	X	X						X						X	
APX-76A	IFF Interrogator	Hazeltine Corp. (Electronic Div.)						X	X	X	X							X	X
APX-78	Transporder	Motorola Inc.															X		
APX-101	IFF Transponder	Teledyne					X												X
ARC-51	UHF Command Radio	Rockwell Int. (Collins Radio)	X		X	X													
		Admiral Corp.																	
ARC-51A	UHF Command Radio	Rockwell Int. (Collins Radio)																X	
		Admiral Corp.																	
ARC-57	UHF Command Radio	General Dynamics Corp.		X															
ARC-105	VHF Radio Communication	Rockwell Int. (Collins Radio)						X	X	X									
ARC-109V	UHF Transceiver	Rockwell Int. (Collins Radio)											X	X	X	X	X		
ARC-114	VHF/FM Radio	General Telephone Electr. Corp.	X																
		(Sylvania Electronics Div.)																	
		E-Systems (Memcor Div.)																	
ARC-123	HF Radio	AVCO Corp. (Electronics Div.)											X	X	X	X	X		
ARC-150	UHF Radio	Magnavox Co.										X							
ARC-159	UHF Transceiver	Rockwell Int. (Collins Radio)	X	X														X	
ARC-164	UHF/AM Radio	Magnavox Co.					X												X
ARR-69	UHF Radio Receiver	RCA (Defense Communication Div.)	X			X					X							X	
ARW-67	Radio Guidance	Esterline Corp. (Babcock Electr.)		X															
ARW-73	Radio Guidance	Martin-Marietta Corp.	X	X															
ARW-77	Radio Guidance	Martin-Marietta Corp.			X			X	X	X									
		(Orlando Div.)																	
ASW-25	UHF Digital Data Comm.	Radiation Systems		X	X	X					X								
ASW-27	Data Link	Litton Industries																X	
		(Data Systems Div.)																	
FM-622A	VHF/FM Radio	Magnavox Co.			X		X												
MX-6770U	Interference Blanker Sys.	Unknown											X						
MX-8811A	Interference Blanker Sys.	Navatronics																	
MX-9147/APX	IFF Reply Evaluator	Litton Industries																	X
MX-9287/A	Interference Blanker Sys.	McDonnell Douglas Corp.																	X
UEM-25	X-Band Beacon	Motorola Inc.					X												
Wilcox 807	VHF/AM Radio	Wilcox Electric Co.					X												

Table B-12 (Page 2 of 2)

RADIO COMMUNICATION SYSTEMS

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	TECHNO LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
AIC-14	80.2	12.3							X															
AIC-18	AVG	5.2	207	.0251	22							X					X							
AIC-25	NONE										X													
APX-64V	AVG	29.0	2084	.0139	80		1											X	X	X	X	X		
APX-72	AVG	16.5	479	.0344				X	X	X	X						X						X	
APX-76A	AVG	19.0	726	.0262	170		1						X	X	X	X							X	X
APX-78	AVG	6.0	121	.0496			2															X		
APX-101	AVG	14.7	380	.0387	65		2					X												X
ARC-51	85.5	33.0	1296	.0256	180	63	2	X		X	X													
ARC-51A	92.9	38.0	1300	.0292	180		2																X	
ARC-57	NONE								X															
ARC-105	AVG												X	X	X									
ARC-109V	89.3	30.0	997	.0301	232	72	2											X	X	X	X	X		
ARC-114	NONE							X																
ARC-123	AVG	91.0	4420	.0206														X	X	X	X	X		
ARC-150	AVG																X							
ARC-159	AVG	9.0	173	.0520		74	3	X	X														X	
ARC-164	AVG	17.0	173	.0984	110							X												X
ARR-69	78.5	10.0	318	.0315		65	2	X			X					X							X	
ARW-67	AVG	11.0	500	.0220	46	60	2		X															
ARW-73	109.8	20.0	1322	.0151	170	60		X	X															
ARW-77	96.4	25.0	624	.0401		64	2			X			X	X	X									
ASW-25	79.0	14.0							X	X	X					X								
ASW-27	AVG																						X	
FM-622A	AVG	27.3	604	.0452	116					X		X												
MX-6770U	AVG																	X						
MX-8811A	90.5	5.8	120	.0483	21	70	2																	
MX-9147/APX	75.7	18.0	657	.0274	85																			X
MX-9287/A	NONE	7.2	250	.0288	65																			X
UPN-25	AVG	3.3	39	.0846	350							X												
Wilcox 807	NONE	18.0	646	.0279	302							X												

VARIABLE	CASES	MEAN	STD DEV
COST	26	12.2115	13.3668
COST100	10	10.9100	9.2667
COSTLB	22	0.6809	0.6302
CSTLB100	10	0.6810	0.6407
CURVE	10	87.7800	10.3650
WEIGHT	24	20.0125	17.8256
VOLUME	22	792.5455	956.7532
DENSITY	22	0.0370	0.0206
POWER	16	137.1250	96.5911
YEAR	8	66.0000	5.3719
VACUUM	11	0.1818	0.4045
SOLID	11	0.8182	0.4045
INTGRTD	11	0.0	0.0

Table B-13 (Page 1 of 2)

RADIO NAVIGATION GROUP DATA

RADIO NAVIGATION SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ARA-25	UHF Direction Finder	La Pointe Industries																	
ARA-50	UHF Direction Finder	Rockwell Int. (Collins Radio)	X	X		X					X	X	X	X	X	X		X	
ARA-63	Receiver Decoder	Cutler-Hammer (Airborne Inst. Lab.) Stewart-Warner Corp.	X			X					X							X	
ARN-14	TACAN Navigation	Rockwell Int. (Collins Radio)																	
ARN-21	TACAN Navigation	Ccurter																	
ARN-52	TACAN Navigation	ITT Corp. (Federal Labs.) Republic Electronics	X		X	X							X	X	X	X	X	X	
ARN-58A	Instrument Landing Sys.	Rockwell Int. (Collins Radio) Ccurter											X	X	X	X	X		
ARN-65	TACAN Navigation	Hoffman Electronics Corp. (Military Electronics Div.)										X							
ARN-83	VHF Direction Finder	Rockwell Int. (Collins Radio)						X	X	X									
ARN-84	TACAN Navigation	Hoffman Electronics Corp. (Military Electronics Div.) ASC Systems Corp.	X	X		X						X						X	
ARN-86	TACAN Navigation	Stewart-Warner Corp.									X								
ARN-92	LORAN C/D Navigation	ITT Corp. (Federal Labs.)			X				X										
ARN-101	LORAN	Lear Siegler Inc. (Instrument Div.)								X									
ARN-108	Instrument Landing Sys.	Rockwell Int. (Collins Radio)					X												
ARN-112	Instrument Landing Sys.	Rockwell International																	X
ARN-118	TACAN	Rockwell Int. (Collins Radio)					X												X
OA-8639/ARA	Automatic Direction Finder	Rockwell Int. (Collins Radio)																	X
OA-8697/ARD	UHF/ADF	Rockwell Int. (Collins Radio)					X												

Table B-13 (Page 2 of 2)

RADIO NAVIGATION SYSTEMS

DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	TECHNO YR	TECHNO LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ARA-25	AVG	8.0	589	.0136			1																	
ARA-50	AVG	7.0	346	.0202	45	65	2	X	X		X					X	X	X	X	X	X		X	
ARA-63	100.0	13.0				72	2	X			X					X							X	
ARN-14	AVG																							
ARN-21	AVG																							
ARN-52	92.3	51.0	2305	.0221	420	64	1	X		X	X							X	X	X	X	X	X	
ARN-58A	AVG	19.0				70	1											X	X	X	X	X		
ARN-65	AVG																X							
ARN-83	AVG												X	X	X									
ARN-84	98.1	29.0	766	.0379	163	71	3	X	X		X						X						X	
ARN-86	95.7	39.0	1037	.0376	250											X								
ARN-92	90.0	91.5	3136	.0292		67	2			X				X										
ARN-101	AVG	44.0	2108	.0209	280										X									
ARN-108	AVG	8.0	216	.0370	45							X												
ARN-112	97.7	6.8	207	.0329	16	72	2																	X
ARN-118	AVG	44.0	2108	.0209	280							X												X
OA-8639/ARA	96.3	12.6	207	.0609	16																			X
OA-8697/ARD	97.9	7.5	487	.0154	28							X												

VARIABLE	CASES	MEAN	STD DEV
COST	18	19.0278	26.2915
COST100	8	24.0625	32.1267
COSTLB	14	0.7321	0.5707
CSTLB100	8	0.7025	0.4085
CURVE	8	96.0000	3.3119
WEIGHT	14	27.1714	24.5568
VOLUME	12	1126.0000	1014.3794
DENSITY	12	0.0290	0.0132
POWER	10	379.3000	758.3923
YEAR	7	68.7143	3.3523
VACUUM	8	0.3750	0.5175
SOLID	8	0.5000	0.5345
INTGRTD	8	0.1250	0.3536

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MISCELLANEOUS AVIONICS SYSTEMS GROUP DATA

MISCELLANEOUS SYSTEMS			AIRCRAFT																
DESIGNATOR	FUNCTION	MANUFACTURER	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ASN-105	Navigation System	Sundstrand Data Control																	
ASQ-119	Astrotracker	Litton Industries															X		
ASN-32	Autoflight System	Honeywell Inc.																	
ASN-40	Flight Control	Sperry Rand Corp.																	
CMI Antenna	Com.Nav.Ident.Ant. (F-15)	Transco Products Inc. Rockwell Int. (Collins Radio) Dorne and Margolin Daico																	X
CV-3194	Data Converter	Litton Industries		X															
KIR/1A/TSEC	Interrogator Computer	NSA (National Security Agency)																	X
KIT/1A/TSEC	Transponder Computer	NSA (National Security Agency)																	X
KY-28/TSEC	Secure Speech	NSA (National Security Agency)																	X
Mag.Azi.Det.	Mag. Azi. Det. (F-15)	Sperry Rand Corp.																	X
T-1217/AR	Attack Sensor	Teledyne																	X
Tot.Temp.Prb.	Total Temp. Probe (F-15)	Rosemount																	X

Table B-14 (Page 2 of 2)

MISCELLANEOUS SYSTEMS								AIRCRAFT																
						TECHNO																		
DESIGNATOR	LEARN CURVE %	WEIGHT LBS.	VOLUME CU.IN.	DENSITY LBS/ CU.IN.	POWER VA	YR	LVL	A-4M	A-6E	A-7D	A-7E	A-10A	F-4C	F-4D	F-4E	F-4J	F-5E	F-111A	F-111D	F-111E	F-111F	FB-111A	F-14A	F-15A
ASN-105	105.4	6.8	256	.0266	89	70	3																	
ASQ-119	AVG	66.0	3629	.0182		67	2															X		
ASW-32	86.9	87.3	1341	.0651	201	70	3																	
ASW-40	102.5	55.8	2592	.0215	180	70	3																	
CNI Antenna	NONE	12.0			22																			X
CV-3194	103.7	29.0	1210	.0240	100	72	2	X																
KIR/1A/TSEC	NONE	13.1	276	.0475	35																			X
KIT/1A/TSEC	NONE	12.1	276	.0438	30																			X
KY-28/TSEC	NONE	16.0	440	.0364	30																			X
Mag.Azi.Det.	101.2	1.6	17	.0941																				X
T-1217/AR	94.6	3.9	53	.0736	310																			X
Tot.Temp.Prb.	NONE	2.2	7	.3143	400																			X

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N-1685-AF *An Analysis of Combat Aircraft Avionics Production Costs,* by J. Dryden, T. Britt, S. Binnings-DePriester. March 1981.

The following corrections should be made on page 36:

Equation

$$\text{COST} = 1.58\ \underset{(.01)}{\text{VOLUME}^{1.52}}\ \underset{(.01)}{e^{.11\ \text{FSTFLT}}}$$

Data and Results

The last two entries for the A-4M line should read:

Residual	|%|
$-212 K-78	56